# NASA Tech Briefs

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Space Administration
October 1992 Vol. 16 No. 10

Transferring Engineering
Technology to Over 200,000
Qualified Readers Throughout
Industry and Government

## Automated Fiber Placement: A Major Advance In Composites Manufacturing

# TONIGHT YOUR DATA IS GOING HOME WITH SOMEONE ELSE.


Your financial statements, payroll records, customer lists, secret designs. What if some of that information – or all of it – got into the wrong hands? If stolen, it could compromise your competitive edge. Or *worse.*

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Protect your valuable data with the 8mm tape drive that demands proof of identity up front, the CY-8500 with data encryption.

Each time you backup sensitive data, insert the 8mm tape – and your card key. The data will be uniquely encrypted to your specific key. The same key will be required to read the data later. So you get up to 25 GB capacity, fast transfer rates, and unsurpassed reliability. All you lose is a security risk. An interloper won't be able to read or write the first byte.

Security doesn't mean a loss of flexibility. You can still read 8mm tapes written on standard drives. High level card holders can still write tapes without data encryption for easy data exchange.


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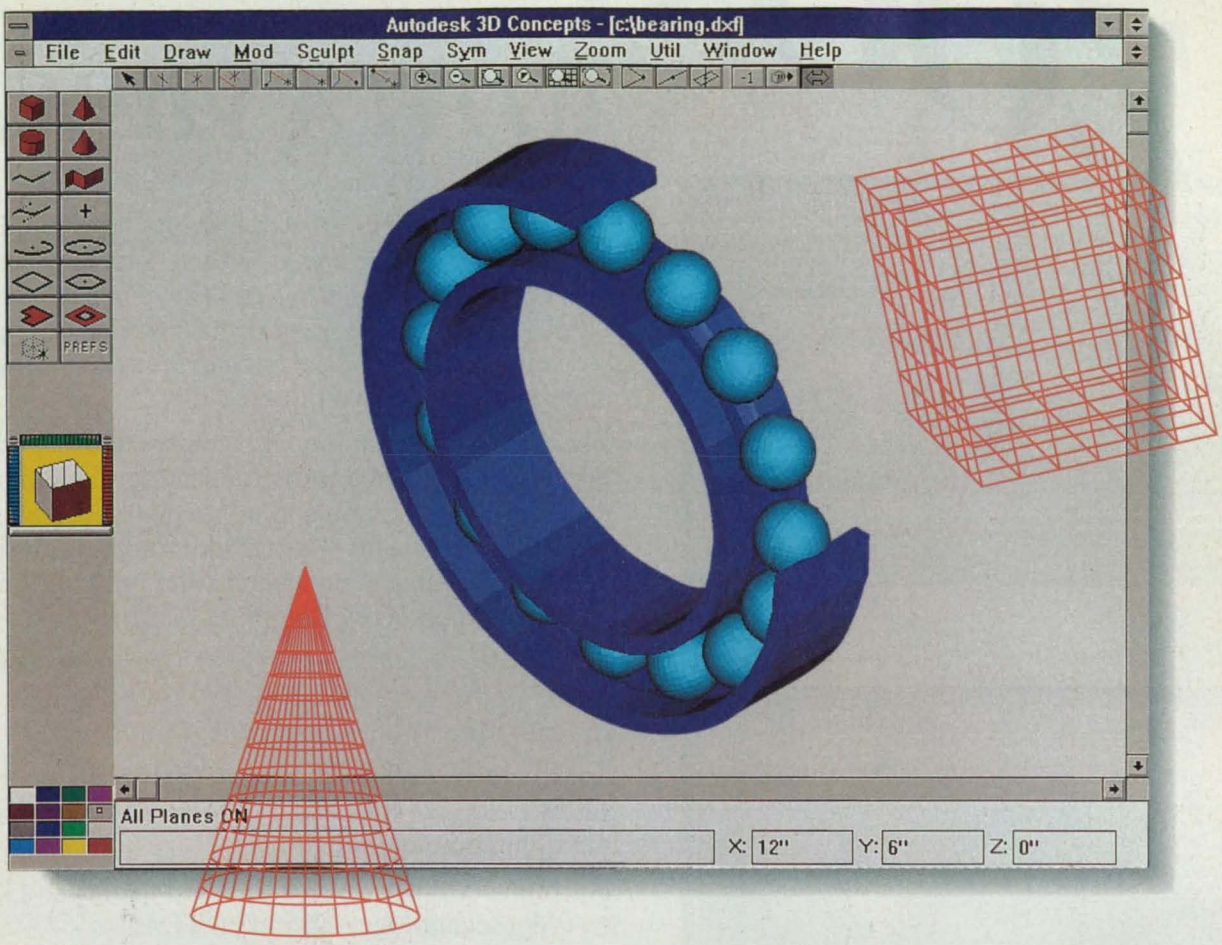


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- ▶ *Light Source Shading*
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- ▶ *Transfers to other Windows programs*

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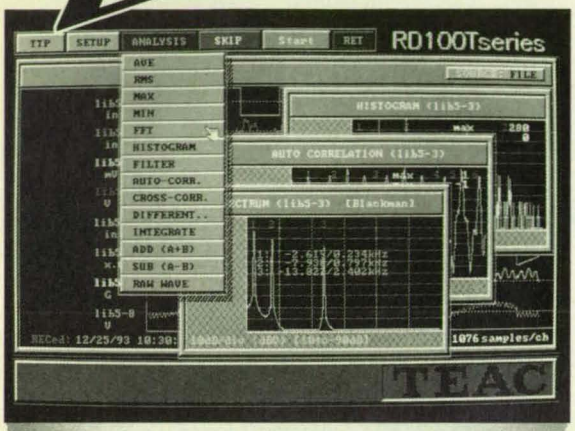
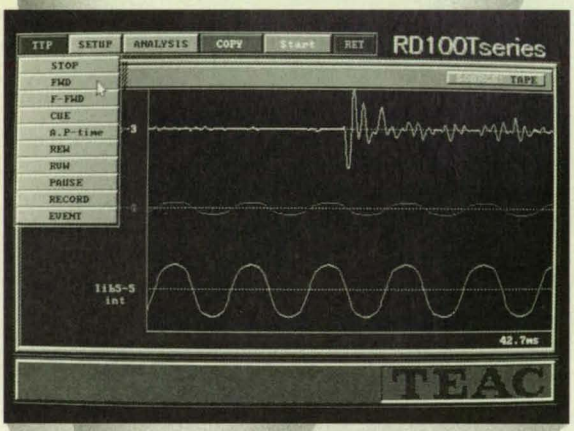
# ZOOM

## *WITH A VIEW!*

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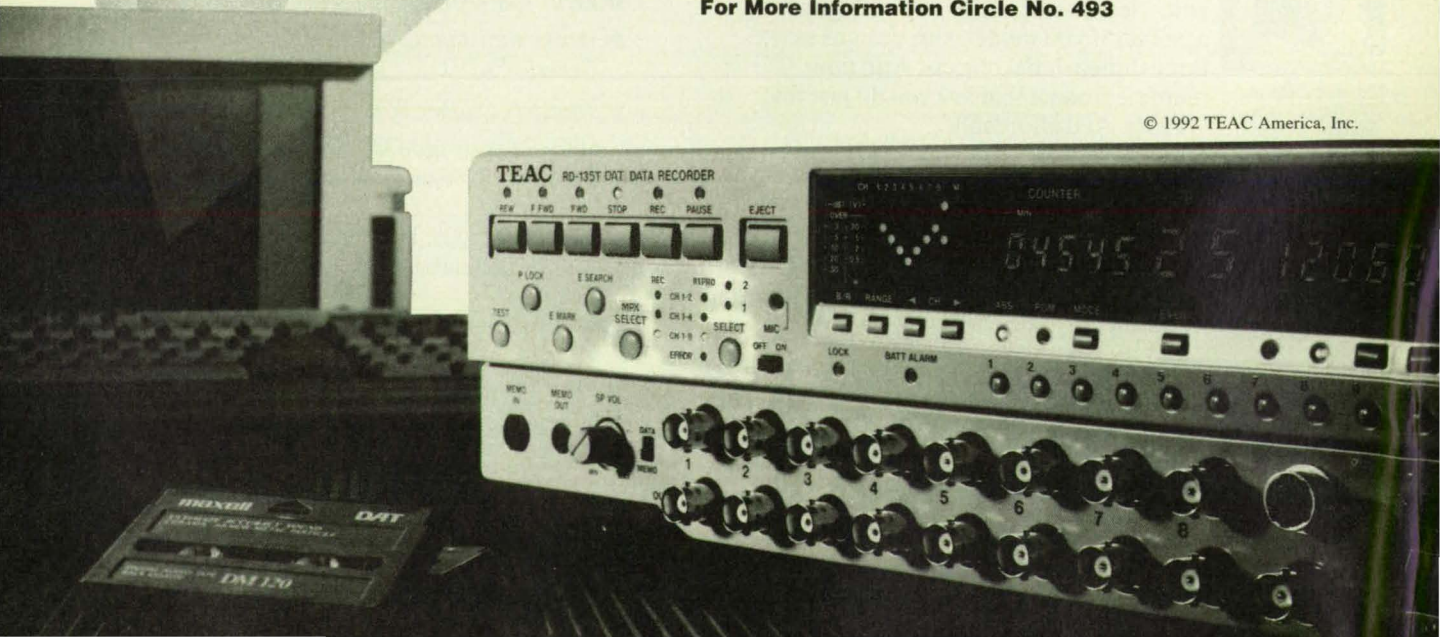

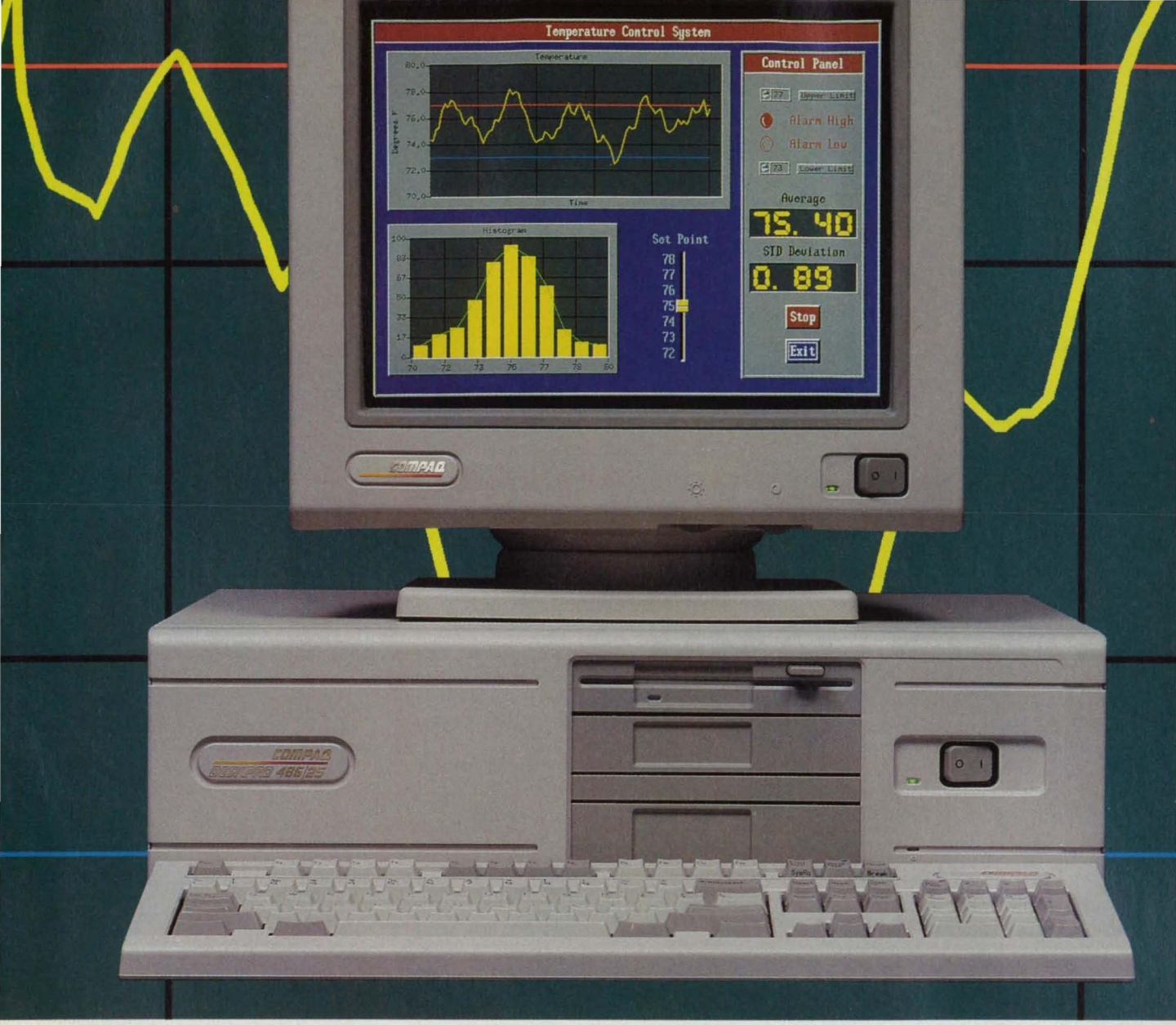


# Take a Look at LabWindows®

LabWindows brings a new look to data acquisition and instrument control. The new look is graphical–a graphical user interface for your acquisition and control system.

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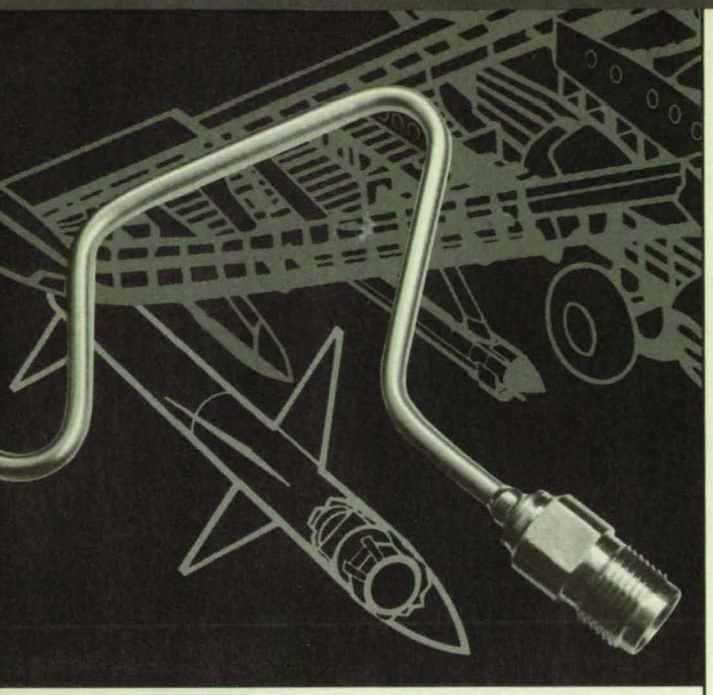
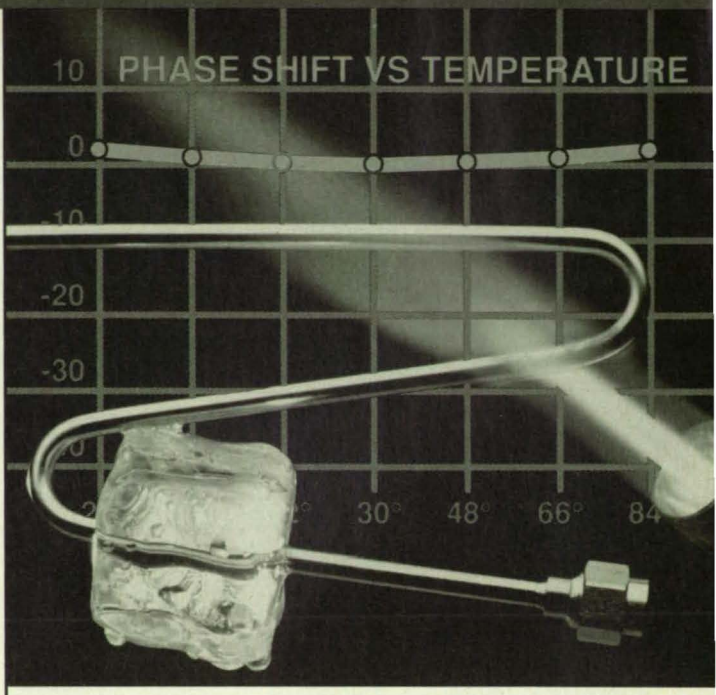





# It has to go where?!

Any microwave integration engineer knows the formidable task of routing coaxial cable through crowded airframes, jammers, missiles, even satellites. Despite the platform, Kaman's semiflexible cable solves these routing obstacles. Although the exterior of Kaman's semiflexible cable looks like PTFE semirigid cable, only $SiO_2$ dielectric withstands the extreme heat required to fully anneal the stainless steel sheath. The annealing process produces a cable that can be continuously rebent. This, combined with no migration of the center conductor, results in little change in electrical performance, unlike PTFE. $SiO_2$ cable is also 30% smaller in diameter, 30% lighter per foot, and withstands up to a 60% tighter bending radius than flexible PTFE cable of equal insertion loss per foot. Kaman laser welds hermetically sealed connectors to the cable sheath and produces a hermetic assembly suitable for the most hostile environments. To learn more about Kaman's custom EW interconnects, call for a free Custom RF Cable Assemblies Handbook.

***KAMAN SPECIFICATIONS***

**$SiO_2$ SEMIFLEXIBLE CABLE**

**Frequency:** Up to 26.5 GHz.

**Electrical length change:** 7 ppm/°C typical (0.0007%/°C).

**Insertion loss change with temperature:** 1000 ppm/°C typical (0.1%/°C).

**Construction:**
*Outer sheath:* Fully-annealed seamless 304 stainless steel tubing.
*Outer conductor:* Oxygen-free copper tubing.
*Dielectric:* $SiO_2$.
*Inner conductor:* Oxygen-free copper.

**Connectors:** Typical MIL-SPEC including SMA and TNC. Also Quick Disconnect, Blind Mate, and other custom designs. Hermetically sealed and laser welded to cable sheath.

**Qualifications:** MIL-T-81490, MIL-C-39012.

**Cable diameters (inches):** .090, .125, .141, .200, .270, .295.

**Bend radius:** 3x cable diameter. At factory, 1.5x cable diameter.

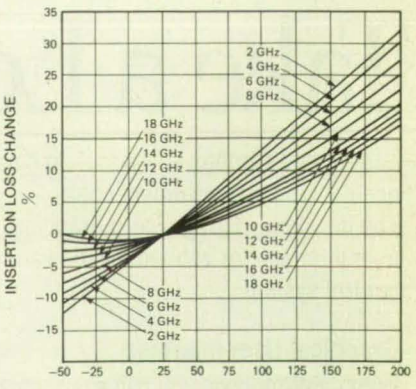
**MTBF:** 1,000,000 hours

*Kaman Instrumentation*
*1500 Garden of the Gods Rd.*
*Colorado Springs, CO 80907*
*719-599-1821 FAX 719-599-1823*

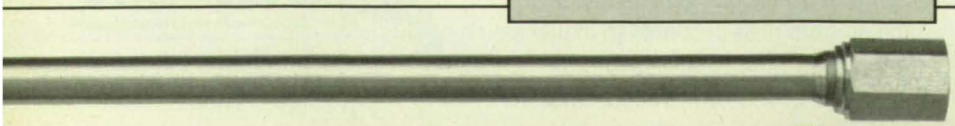
**800-542-2443**

# ...and do what?!

Kaman's cables connect laboratory ideas to platform reality by offering virtually flat phase shift over temperature. This eliminates temperature compensation and frequent phase calibration prohibited by reaction-time budgets. In EW airborne applications, flight-line to 40,000-foot temperature swings would cause phase drift from non-$SiO_2$ cables. Insertion loss change over temperature is also drastically reduced compared to PTFE cables.




INSERTION LOSS CHANGE VS TEMPERATURE FOR A TYPICAL .141 DIAMETER CABLE



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October 1992
Volume 16 Number 10

# Contents

NASA Tech Briefs
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Throughout Industry and Government

## SPECIAL FEATURE

**12 NASA's Innovators**

## TECHNICAL SECTION

**22 Electronic Components and Circuits**

**22** SNS Heterojunctions With New Combinations of Materials
**22** Circuits Protect Against Incorrect Power Connections
**26** Improving Current Balance in Parallel MOSFET's
**26** Superconductive Coplanar-Waveguide Filters
**30** Optical Link for Readout From Focal-Plane Array
**32** Photofabricated Wire-Grid Polarizers

**34 Electronic Systems**

**34** Robots Would Couple and Uncouple Fluid and Electrical Lines
**34** Generating Multiple Calibrating Voltages Simultaneously
**36** Scanning-Pencil-Beam Radar Scatterometer
**36** Programmable Hyperspectral Imaging Mapper
**37** Radar Altimetry for Topographical Mapping
**40** Reconfigurable Fuzzy Cell
**42** Fast Vector-Quantizing Data Compressor
**44** Publication of Oceanographic Data on CD-ROM
**44** Tracking Comb Filter Suppresses Welder Harmonics
**45** Optical Correlator With Complex Holographic Filter
**46** Arraying Techniques in the Deep Space Network

**57 Physical Sciences**

**57** Slow-Positron Generator for Studying Polymer Films
**57** Liquid-Arc/Spark-Excitation Atomic-Emission Spectroscopy
**58** Irradiation by Neutrons and Annealing of SiGe Alloys
**60** Tables of Gaussian-Type Orbital Basis Functions
**62** Nonequilibrium Effects in Hypervelocity Flow
**62** Mode/Medium Instability in $CO_2$ Laser
**63** Accuracy of the Correlated-*k* Method
**64** Ties Between Celestial and Planetary Reference Frames
**65** Lightning-Sensor Data Help in Understanding Thunderstorms
**66** Aspects of 40- to 50-Day Oscillations in LOD and AAM

**67 Materials**

**67** Superconducting Films on Microwave Dielectric Substrates
**67** Polyphosphazene Icephobic Coating Materials
**68** Indium Helps Strengthen Al/Cu/Li Alloy
**68** Tailoring Laminates for Protection Against Projectiles
**71** High-Performance Positive Paste for Lead/Acid Batteries
**71** Carbon/Carbon Fasteners for Use at High Temperatures
**72** Carborane Dopant Strengthens Pitch Char
**72** Multishock Shield Against Meteoroids and Debris
**72** Effects of Irradiation by Electrons on Two Polyimides
**73** Tests of Polyurethane and Dichromate Coats on Aluminum
**73** Alloys for Flexible Hoses in a Corrosive Environment

**74 Computer Programs**

**74** Computing Thermodynamics of Cryostorage Tanks in Orbit
**74** C Language Integrated Production System, Version 5.0
**76** Efficient Two-Dimensional-FFT Program
**77** Software for Genetic Algorithms

**78 Mechanics**

**78** Robotic Gripper Resists Torsion and Lateral Forces
**78** Preliminary Design for Adhesively Bonded Composite Joints
**80** Sleeve Protects Axle When Wheel Is Changed
**81** Fixed or Controlled-Movement Foot Restraint
**81** Contraction-Only Exercise Machine
**82** Two Algorithms for Hypersonic Computations

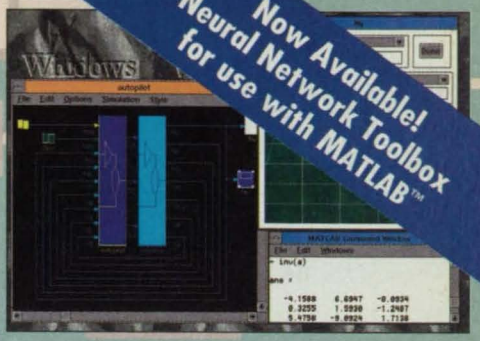
*(Continued on page 8)*

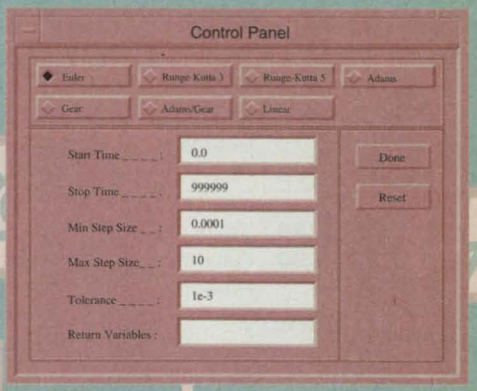
NOW AVAILABLE FOR MICROSOFT WINDOWS

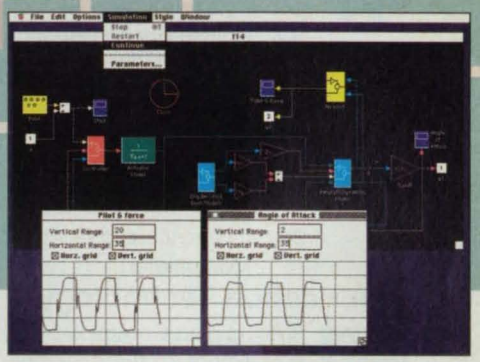
Now Available! Neural Network Toolbox for use with MATLAB™

# SIMULINK™

## *Block Diagram Software for Nonlinear Simulation of Dynamic Systems*





(Top) Use the Scope block to see the "real-time" response of this autopilot model during the simulation; (Center) Specify simulation parameters via dialog boxes or the MATLAB command line; (Bottom) SIMULINK takes full advantage of the X Windows, OSF/Motif, Microsoft Windows, and Macintosh windowing systems.

SIMULINK, formerly named SIMULAB, is the next-generation software for modeling, analyzing, and simulating nonlinear systems. **SIMULINK** delivers a combination of flexibility, ease-of-use, and speed in a single package.

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- An intuitive graphical user interface based on the industry-standard X Windows™, OSF™/Motif™, Microsoft® Windows™, and Macintosh® windowing systems.

**SIMULINK** provides you with the tools for constructing and analyzing block diagram models interactively using a mouse and pull-down menus. You can explore the behavior of a system during a simulation and interactively see how the model's behavior changes as you change its parameters.

**SIMULINK** includes a comprehensive set of built-in blocks for creating models. In addition, **SIMULINK** lets you extend its functionality by creating your own tools. Customize built-in **SIMULINK** blocks or create your own as C, Fortran, or **MATLAB** code. **SIMULINK** delivers the flexibility to meet your needs.

**SIMULINK** is available for a wide range of computers, including UNIX® workstations, 386- and 486-based PCs, and the Apple® Macintosh. For more information on how **SIMULINK** can address your applications, contact The MathWorks today for a free information packet.



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**For More Information Circle No. 503**

# Contents *(continued)*


**83** Compliant Robot Wrist
**84** Enhancing Control of Helicopter Yaw at Low Speed
**85** Ultrasonic Dynamic Vector Stress Sensor
**85** Screens Would Protect Wind-Tunnel Fan Blades
**86** Windshield-Wiper Heater
**87** Positive Stop for Circulation-Control Slot
**88** Scaling of Responses of Composite Beams
**88** Active Suppression of Vibrations in a Truss
**89** Tests of Array of Flush Pressure Sensors
**90** Habitable Wardroom for Space Station Freedom

## 91 Machinery

**91** Improved Superconducting Magnetic Rotary Bearings
**92** Foldable Large Reflectors
**92** Rolling-Friction Robotic Gripper
**94** Split-Rail, Rolling-Friction Robotic Gripper With Tool Drive
**95** Electrically Controlled Valve With Small Motor
**96** Study of Robotic Replacement of Equipment Modules
**96** Dynamics and Control of Flexible Manipulator

## 97 Fabrication Technology

**97** Joining Ceramics by Brazing
**97** Robot Would Assemble Collet/Flexible-Drive Truss Joint
**98** Making Conductive, Compliant Heat-Transfer Pads
**99** Artificial Intelligence Assists Ultrasonic Inspection
**99** In Situ Robotic Inspection of Welds
**100** Modified Spot Welder Solders Flat Cables
**101** Laser Shearography Reveals Hidden "Unbonds"

## 103 Mathematics and Information Sciences

**103** Hand/Eye Coordination for Fine Robotic Motion
**103** Dynamic Restructuring of Problems in Artificial Intelligence
**105** Scheme for Finite-Difference Computations of Waves
**106** Front-End Processor for Metrology-Information System
**107** Optimizing Reduced-Order Transfer Functions
**108** Space-Time Neural Networks
**110** Automated Simulation for Analysis and Design
**110** Analyzing Robotic Kinematics via Computed Simulations
**111** More About Generating Three-Dimensional Grids About Anything

## 112 Life Sciences

**112** Electrophoretic Process for Purifying Wastewater
**112** How Humans Adapt to Heat
**113** Training for Estimation of Angles via Perspective Displays
**113** U.S. Biomedical Experiments in a Soviet Biosatellite


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# DEPARTMENTS


**New Product Ideas** ..... 18
**NASA TU Services** ..... 20
**New on the Market** ..... 114
**New Literature** ..... 116
**Subject Index** ..... 132
**Advertisers Index** ..... 138


**on the cover:**

***The world's first automated fiber placement system (FPS) is housed at NASA's Marshall Space Flight Center in Alabama. Combining the advantages of filament winding, contour tape laying, and in-process lamination with robotics and computer control, the FPS produces complex composite parts for a variety of applications. Turn to NASA's Innovators, page 12.***




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# SCIENCE/SCOPE®

A series of massive Hughes Aircraft Company-built satellites can carry as many as 120,000 phone calls and three TV channels simultaneously. These satellites, which are being used by the International Telecommunications Satellite Organization (INTELSAT), stand nearly four stories tall and weigh 4.5 tons. In comparison, the world's first commercial communications satellite, Early Bird, built by Hughes 27 years ago, was two feet tall, weighed 76 pounds, and could carry only 240 phone calls or one TV channel.

In what is likely the most intricate satellite replacement scenario ever, Hughes will soon launch its first pair of dual-payload satellites, Galaxy IV and Galaxy VII. They will replace Hughes' existing Ku-band and C-band satellites at the orbital positions of 99 degrees and 91 degrees, respectively. What makes this especially complicated is that they will be launched within four months of one another, requiring an unprecedented feat of choreography that includes backup satellites both in orbit and on the ground. This will enable Hughes to maintain ongoing, uninterrupted service to existing customers, who collectively have more than 25,000 satellite dishes — mostly in fixed positions — pointed at their existing fleet.

In a dramatic breakthrough that will help save the earth's ozone layer, Hughes has developed an alternative manufacturing process that does not require rosin-based fluxes in soldering circuit card assemblies. The new process uses a citric acid-based substance called HF1189, which provides a higher quality bond during soldering, yet requires only water to clean off the completed circuit board. Until now, conventional rosin-based fluxes were cleaned with solvents containing ozone-depleting chlorofluorocarbons (CFCs). Of the 3 billion pounds of CFC-based chemicals used each year, 16% — or roughly 500 million pounds — can be linked to industrial solder fluxing and cleaning operations. As Hughes makes this new process available industry-wide, these statistics are likely to drop considerably.

Now, in times of disaster, even the most isolated outposts can be linked directly into the public telephone network. It's the result of portable versions of satellite earth stations called very small aperture terminals (VSATs), built by Hughes. VSATs played a vital role in three major relief efforts in 1991: the eruption of Mt. Pinatubo in the Philippines, the massive oil spill in Valdez, Alaska, and the 90,000-acre fire in the Idaho forest. VSATs can be shipped and assembled quickly and facilitate communications using more powerful antennas that are much smaller than conventional satellite dishes. The Hughes-designed networks' reliability and an availability rate of 99.5 percent make VSATs an excellent solution to conventional communications systems, which in disasters often experience serious degradation due to damage or overload.

City transit buses throughout the country are benefitting from fire sensing and suppression systems once reserved for military vehicles, such as Bradley and M-1 tanks. These Hughes systems can detect and extinguish a fire in a fraction of a second, protecting lives and equipment. They are especially effective now, as cities are using alternative, clean-burning fuels, such as methanol, to comply with the Federal Clean Air Act. Unfortunately, methanol's blue flame is hardly visible. It takes a fire suppression system such as this to detect it instantly.

For more information write to: P.O. Box 80032, Los Angeles, CA 90080-0032

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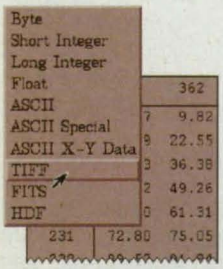


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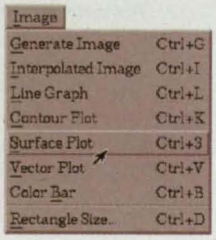


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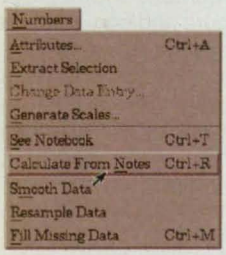


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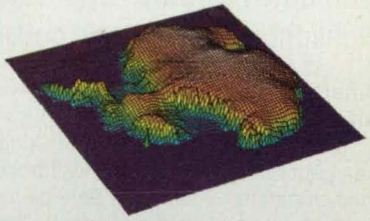
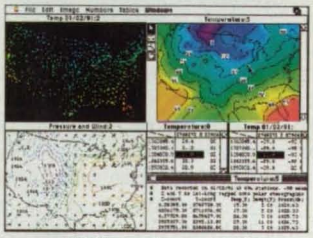
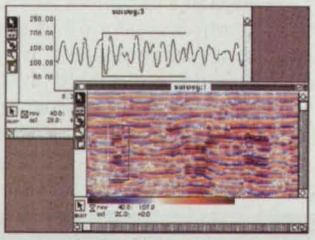


Surface elevation of Antarctica
Data: Professor Doug MacAyeal, Univ. of Chicago



U.S. Weather, January 2, 1991
Data: University of Illinois at Urbana-Champaign Dept. of Atmospheric Sciences

Simulation of wind flow over an airfoil at Mach 0.5
Data: Dr. Mark Christon, Lawrence Livermore Labs



Slice from 3D seismic survey
Data: Halliburton Geophysical Services, Inc.

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# NASA's INNOVATORS

Technology 2002, the third national technology transfer conference and exposition (December 1-3, Baltimore convention center) will feature presentations by over 50 of NASA's leading researchers detailing a broad array of space-based inventions with down-to-Earth applications. In the first of two parts, we highlight some of their cutting-edge work.

## Smart System Checks Aircraft Health

Cost-cutting by commercial airlines has kept many planes aloft well beyond their originally anticipated service lives. A monitoring system developed by Structural Integrity Associates (SI) as part of a Small Business Innovation Research contract with the Lewis Research Center could help keep these aging aircraft safe while optimizing maintenance schedules to further reduce operating expenses.

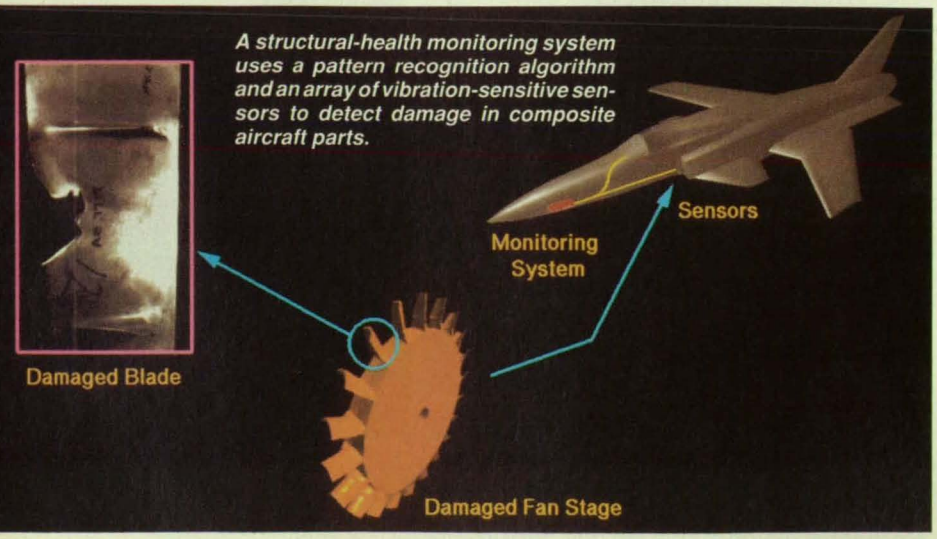
The older the airplane, the more takeoff/landing and pressurization/de-pressurization cycles it has sustained, both of which can contribute to structural degradation. The new microprocessor-based data acquisition system employs an array of strain gauges and accelerometers to monitor the vibrations of in-service parts, from which it can identify the type of damage and degree, the size of the damaged zone, and its precise location. "We monitor the structures so that they are not replaced too soon, which would be wasteful, or left in the fleet too long, which could be very dangerous," said Joseph Grady, a Lewis aerospace engineer involved in the project.

The system is designed to evaluate polymer matrix composites, materials with high strength to weight ratios that are particularly useful in aerospace applications where weight is critical such as horizontal and vertical stabilizers and wing surfaces. The composites are made of a series of adhesively bonded plies, just millimeters thick, that are reinforced with graphite fibers. Over time, the materials are susceptible to various problems. According to Grady, the worst damage is caused by delamination, in which the plies begin to come apart. Other types of damage include cracks in the epoxy matrix or graphite fibers.

Pattern recognition algorithms provide the key to detecting such damage by recognizing trends in the vibration signals. The algorithm bases its inferences on previous test case experience, in which it has been trained using various damaged components. "Results obtained with the pattern recognition algorithm have correlated well with the actual damage," said Grady.

Current nondestructive evaluation techniques used to assess structural health require the plane be taken out of service periodically. Furthermore, they are local techniques, performing a sort of spot-checking—the more spots checked, the more time required. The SI system operates while the plane is in service and monitors the entire composite structure at once.

The technology is applicable to any rotating structure subject to fatigue such as turbine and compressor engine blades, and is currently used in nuclear power plants worldwide. The algorithm also could provide an efficient inspection method for manufacturing quality assurance.




*A structural-health monitoring system uses a pattern recognition algorithm and an array of vibration-sensitive sensors to detect damage in composite aircraft parts.*

## A Boon To The Composites Industry

Manufacturing advanced composite parts is a tricky process, hence the variety of techniques. Filament winding works well for simple round shapes. Tape laying efficiently generates large flat or gently contoured surfaces such as aircraft wing skins. But what if the part is smaller and more complex, with concave and other assymmetrical configurations?

Fiber placement technology provides the means to automate the manufacture of complex composite structures. It offers both the motion characteristics of a filament winder and the fiber lay-up attributes of a tape laying machine. Automation eliminates the expensive manual efforts customarily associated with complex geometries and offers better quality control.

The world's first automated fiber placement system (FPS) was built at the Marshall Space Flight Center's Productivity Enhancement Complex as a joint venture of Cincinnati Milacron Inc. and Thiokol Corp. The FPS is owned by Thiokol, which supports materials and processes R&D in collaboration with Marshall.

"There are so many components produced partially with automation and partially by hand," said John Vickers, a Marshall aerospace engineer. "By automating the manual portions, the machine eliminates labor hours and can produce more uniform, higher-quality parts."

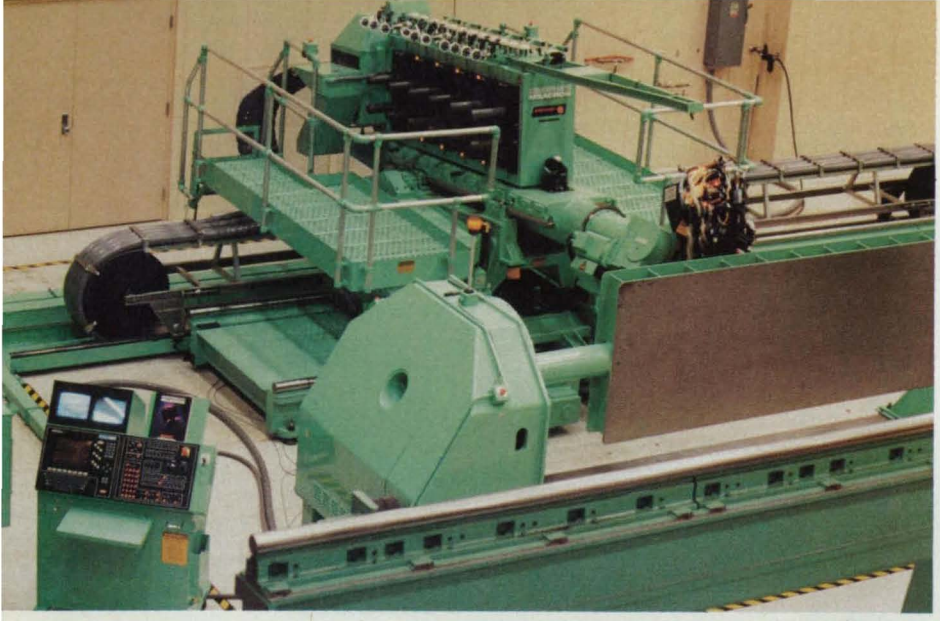
The FPS's one-step process uses rollers to compact up to 24 1/8" tows on a rotating or nonrotating mandrel or tool surface to create flat, convex, concave, or compound geometrical shapes. Advantages include reduced vacuum debulking, increased flexibility, differential tow payout speeds, and cut-restart.

The FPS is available to composite parts manufacturers from Cincinnati Milacron, which markets the machine under the trade name "Viper," and will conduct preliminary tests to demonstrate the system's cost-effectiveness. According to the company, it enables profitable fabrication of such parts as engine ducts, blades, struts, propellers, fuselages, nozzle cones, and tapered casings. The machine also expands the variety of parts that can be efficiently produced using advanced composites such as graphite epoxy, fiberglass, and Kevlar®.

## A "Magic Bullet" For Cancer Treatment

A new weapon in the battle against cancer both predicts the risk of metastasis and holds promise for the first direct means of preventing it. Metastasis, or the transfer of malignant cells through the body to form new tumors, remains a grave threat despite recent advances in cancer therapy.

For cancer cells to migrate through tissue, they must secrete an enzyme,



***The automated fiber placement system at Marshall Space Flight Center manufactures complex 3D composite structures.***

literally dissolving their way to new sites. The enzyme urokinase is the primary culprit in cancers of the breast, and likely is responsible in metastasis of colon, prostate, lung, ovarian, uterine, and brain tumors. A technique under development at the Johnson Space Center (JSC) measures urokinase levels in individual cells, enabling physicians to detect specific ones on the verge of metastasis.

"The range of urokinase concentrations is very broad from cell to cell and patient to patient," explained Dennis Morrison, senior biotechnology scientist at JSC. "These variations no doubt are linked to factors such as when the tumor was removed."

JSC has developed monoclonal antibodies that bind selectively to urokinase. Labelling the antibodies with fluorescence permits direct imaging of the varying urokinase concentrations on cells within a single tumor (see photo below). The images are converted to digital format, selectively enhanced, and used to measure the cells' urokinase levels and thereby predict the risk of metastasis.

According to Morrison, current prognosis indicators, such as the number of lymph nodes involved in breast cancer, are very crude. "This tool will make possible much more precise determinations of appropriate follow-up therapy," he said.

A quantitative assessment of tumor aggressiveness tells the surgeon or oncologist whether a particular tumor is actively trying to spread. When a significant number of cells contain large amounts of urokinase, for example, the post-surgical radiation or chemotherapy schedule can be designed to try to stop metastatic cells that may have already left the primary tumor site. The technique also can reveal when a tumor has arisen through metastasis, indicating that the primary tumor must reside elsewhere.

"We anticipate commercial testing of the tool within 18 months," said Morrison. JSC is developing the image analysis technique with DNA Sciences Inc., a medical services company that analyzes biopsies.

"The most exciting aspect of our research is its potential to offer the first anti-tumor therapy that specifically targets cells about to metastasize," said Morrison. Such a "magic bullet" therapy would kill only metastatic cells by attaching chemotherapy drugs or radioisotopes to the urokinase-specific antibodies.

***Brightly glowing spots on these brain tumor cells indicate areas with high concentrations of urokinase, the enzyme that allows metastatic cells to invade adjacent tissues and migrate to new tumor sites.***

### "Natural" Solutions To Engineering Problems

Genetic algorithms (GAs) employing the same techniques that gave our planet its stunning diversity of creatures are proving applicable to a diverse group of science and engineering problems. These highly parallel, adaptive search procedures are based loosely on the mechanics of natural selection and evolution, reaching solutions through "generations" of trial-and-error.

In an effort to broaden the use of GA technology, researchers at Johnson Space Center's Software Technology Branch developed a generic GA tool called Splicer, currently available through COSMIC, NASA's software distribution center at the University of Georgia. "Genetic algorithms allow you to ask 'have I seen this somewhere in nature?' and then provide a means to try out various biological models," said Lui Wang, a JSC computer engineer who has worked with GAs for five years. "It's a very flexible paradigm, helping to stretch the imagination."

GAs can tackle problems in a wide range of fields including digital filter design, gas pipeline control, image processing, pattern recognition, and database system design. They are particularly useful where discontinuous functions preclude solving by traditional calculus-based methods. Applying a GA begins with defining all the parameters relevant to a particular problem and then randomly generating several complete sets of parameter values. Each set, or "chromosome," is tested to see how well it addresses the problem. The better solutions are "mated" with each other by combining parts from each parent chromosome to produce "offspring."

Beginning with the second generation, the computer simulates natural selection by testing the offspring for "fitness," or ability to solve the problem, and reserving the best performers for further breeding. Useful traits tend to survive the process because the individuals carrying them get more chances to breed, while damaging traits are gradually weeded out. Repeated applications of genetic operators such as crossovers and mutations—again mimicking the respective natural processes—culminates in optimal or near-optimal combinations of parameter values.

In the uniquely versatile Splicer GA tool, tasks and rules are divided among four modules. The GA kernel models the evolutionary cycle, determining whether it will follow the "survival of the fittest" rule strictly or merely cull out the weakest population members, as well as assigning chromosomal pairs.

A second module contains the representation libraries that encode crossover functions, which can be single- or multiple-point , and govern whether the chromosomes are haploid or diploid. Diploid chromosomes, like those found in humans, permit recessive traits to be passed from generation to generation without expression. A third module provides three user interface libraries, including both Macintosh and X-Windows user interfaces.

The fitness module, the only one contributed by the user, tells how to differentiate population members, in other words, how to "score" their performance with respect to the problem. This ranking is used to determine which members will survive to "propagate" and how they will

*As part of NASA's Global Change Research Initiative, a plane equipped with LIDAR flies over Greenland to measure snow and ice accumulation.*

### Laser Sheds New Light on Planet Earth

Surveying on foot presents tremendous difficulty when the target site is a swamp. A remote sensing instrument based on NASA laser technology allows surveyors to gather unprecedented volumes of topographical data from wetlands and other Earth environments without getting their feet wet.

The laser ranging device (LIDAR) gathers survey data from aircraft, saving both time and money compared to manually-derived field surveys or aerial photography. Fran Stetina, who helped develop the instrument at Goddard Space Flight Center, describes the increase in productivity in a first-order survey, which typically generates data with a resolution of six inches or better: "Our system puts the accuracy of ground-based crew surveys up in a vehicle going 100 meters per second—that translates into two orders of magnitude more data."

In addition to generalized site surveys, the system is applicable to utility line and hazardous waste site monitoring, oil slick detection, water quality assessment, timber volume estimations, and plant stress and species identification. It can operate in a variety of weather conditions both during the day and at night.

The LIDAR's development team is working to reduce the size, weight, and power requirements of the sensor to fit in a twin-engine aircraft. They expect to have a prototype flying in an aerial survey plane next summer, and to release a commercial version in late 1994. One of the instrument's first challenges will be to support a US Geological Survey project committing $200 million over 10 years to create orthographic projections of the entire US.

The system incorporates an Nd:YAG laser transmitter, optical receivers, a scanning mirror, and a video recorder. Recent integration of a global positioning system and an inertial navigation system permits determination of the aircraft's absolute location and attitude. The resultant data can be fed directly into a computer for analysis, eliminating the need for an interpreter. ❑

*For more information about the technologies described above, contact the NASA field center that sponsored the research (see page 20). The second part of this article will appear in the December issue.*

be paired up. Writing the fitness module allows the user to customize the GA to individual problems. To accommodate users that find writing their own fitness module onerous, researchers at JSC continually strive to minimize user input. They have encoded proven strategies for some classes of problems, such as scheduling problems, into the libraries, leaving only the defining of variables to the user.

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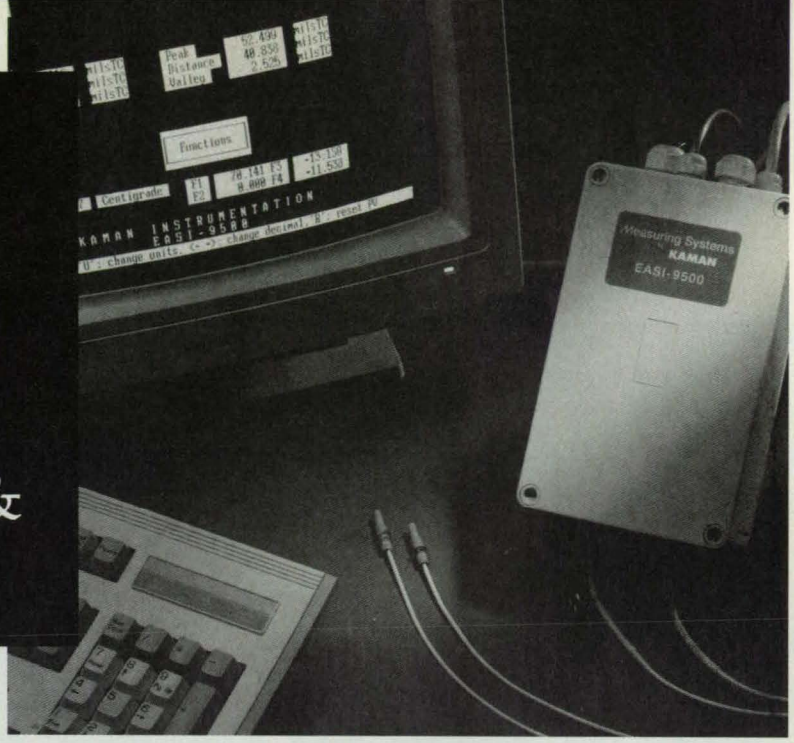


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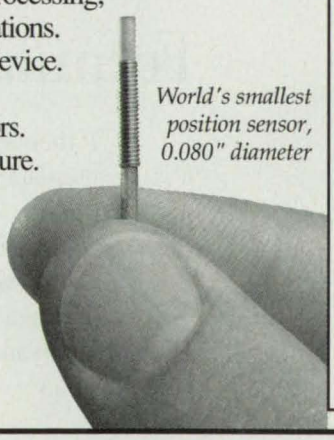

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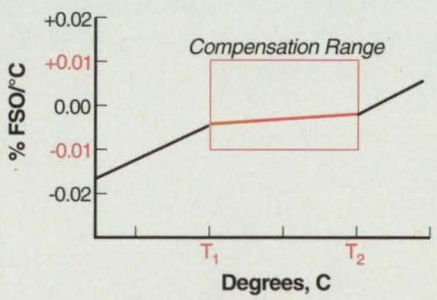


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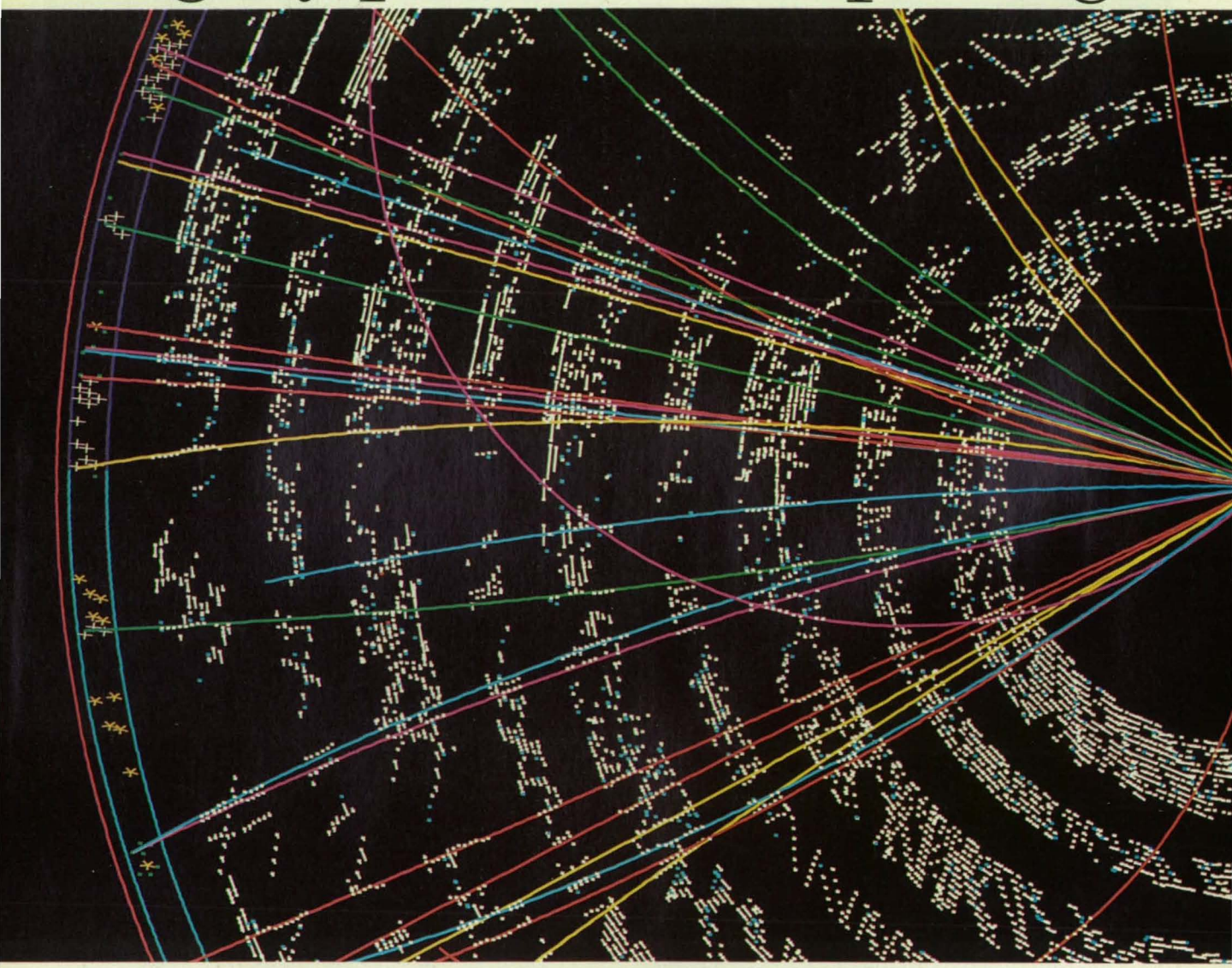
# Highly parallel computing.



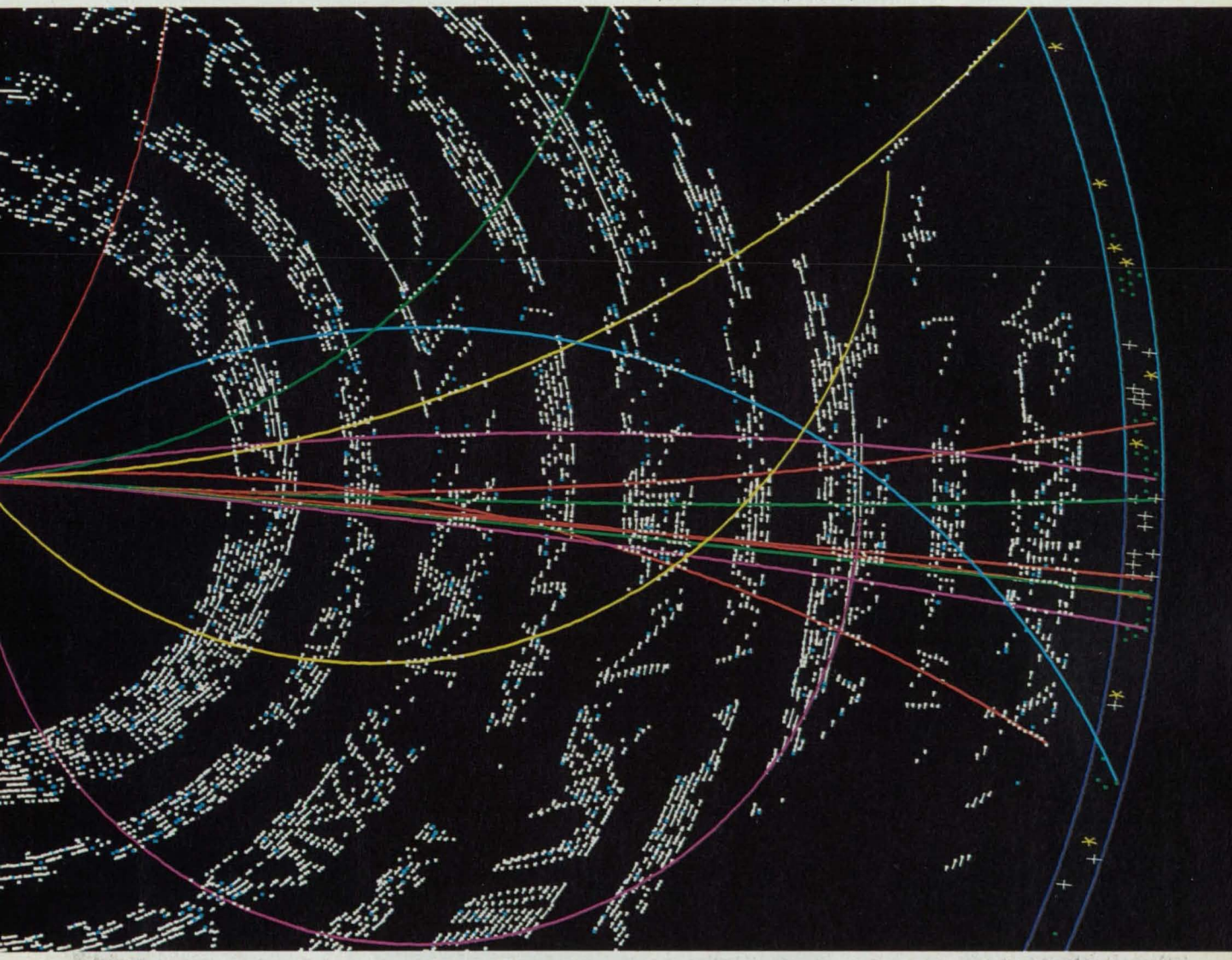
## Fermilab is tapping a new

If there's one thing you can count on in science, it's that your data will increase exponentially but your funding won't.

The scientists at Fermi National Accelerator Laboratory (Fermilab) have encountered this problem in a very big way. The data Fermilab processes for subnuclear event reconstruction and modeling has reached 40 terabytes a year. And they've developed an innovative solution to meet their needs.

Instead of relying on supercomputers, Fermilab has distributed a significant part of the workload to clustered IBM RISC System/6000™ workstations. They've combined 108 of them, at latest count, in a LAN-connected

Computer reconstruction of proton/anti-proton collision at Fermilab.



# source of power.

processor farm. This farm gives Fermilab a full 3,000 MIPS that can be dedicated to a single parallel processing application.

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# New Product Ideas

**New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 20). NASA's patent-licensing program to encourage commercial development is described on page 20.**

## SNS Heterojunctions With New Combinations of Materials

New combinations of materials are proposed for superconductor/normal-metal/superconductor heterojunctions in low-temperature electronic devices, such as fast switches, magnetometers, and mixers. These combinations would provide requisite low chemical reactivity and matching of crystal lattices.
(See page 22.)

## Robotic Gripper Resists Torsion and Lateral Forces

A gripper for the end effector of a robot is shaped so that it tolerates large initial misalignments with an object to be gripped. The gripper consists of a pair of opposing fingers that grasp a mating handle on the object.
(See page 78.)

## Polyphosphazene Icephobic Coating Materials

Coating materials consisting mostly of modified polyphosphazene (class FZ) elastomers offer better protection against icing than fluorocarbon polymers and silicone elastomers. The new coats can reduce the accumulation of ice on aircraft, ships, antennas, and power-transmission lines.
(See page 67.)

## High-Performance Positive Paste for Lead/Acid Batteries

A new paste for positive plates of lead/acid batteries imparts higher discharge currents and higher specific energy than the conventional paste. At a rate of 1 A/cm$^2$, the new plate delivers about 18 A•h/lb (40 A•h/kg), compared to about 6.3 A•h/lb (14 A•h/kg) for the conventional plate.
(See page 71.)

## Improved Superconducting Magnetic Rotary Bearings

These bearings would rely on type II superconducting materials. Type II superconductors have critical magnetic fields and critical temperatures greater than those of type I superconductors and include the well-known ceramic compound $YBa_2Cu_3O_x$.
(See page 91.)

## Split-Rail, Rolling-Friction Robotic Gripper With Tool Drive

A robotic gripper includes a split-rail drive assembly that moves two gripping fingers toward or away from each other. The fingers are equipped with rollers that mate with recesses and seating ramps on a specially designed object.
(See page 94.)

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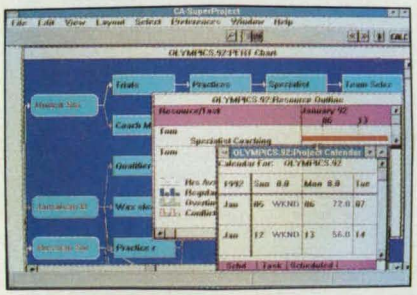

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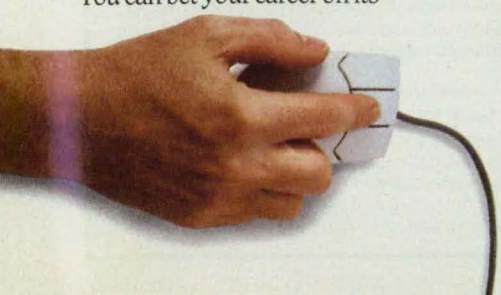

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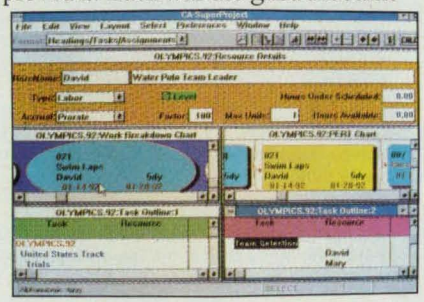

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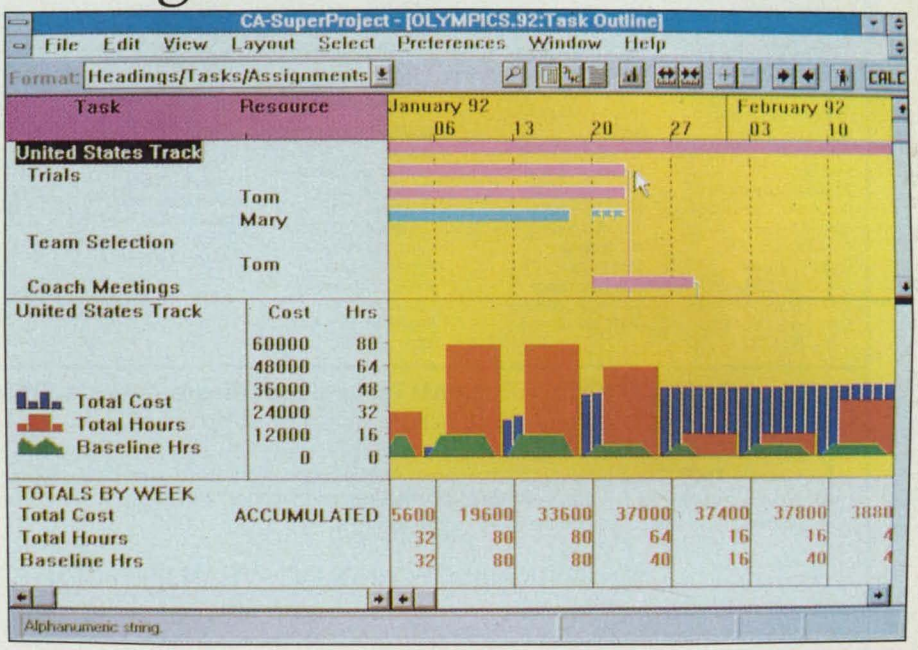


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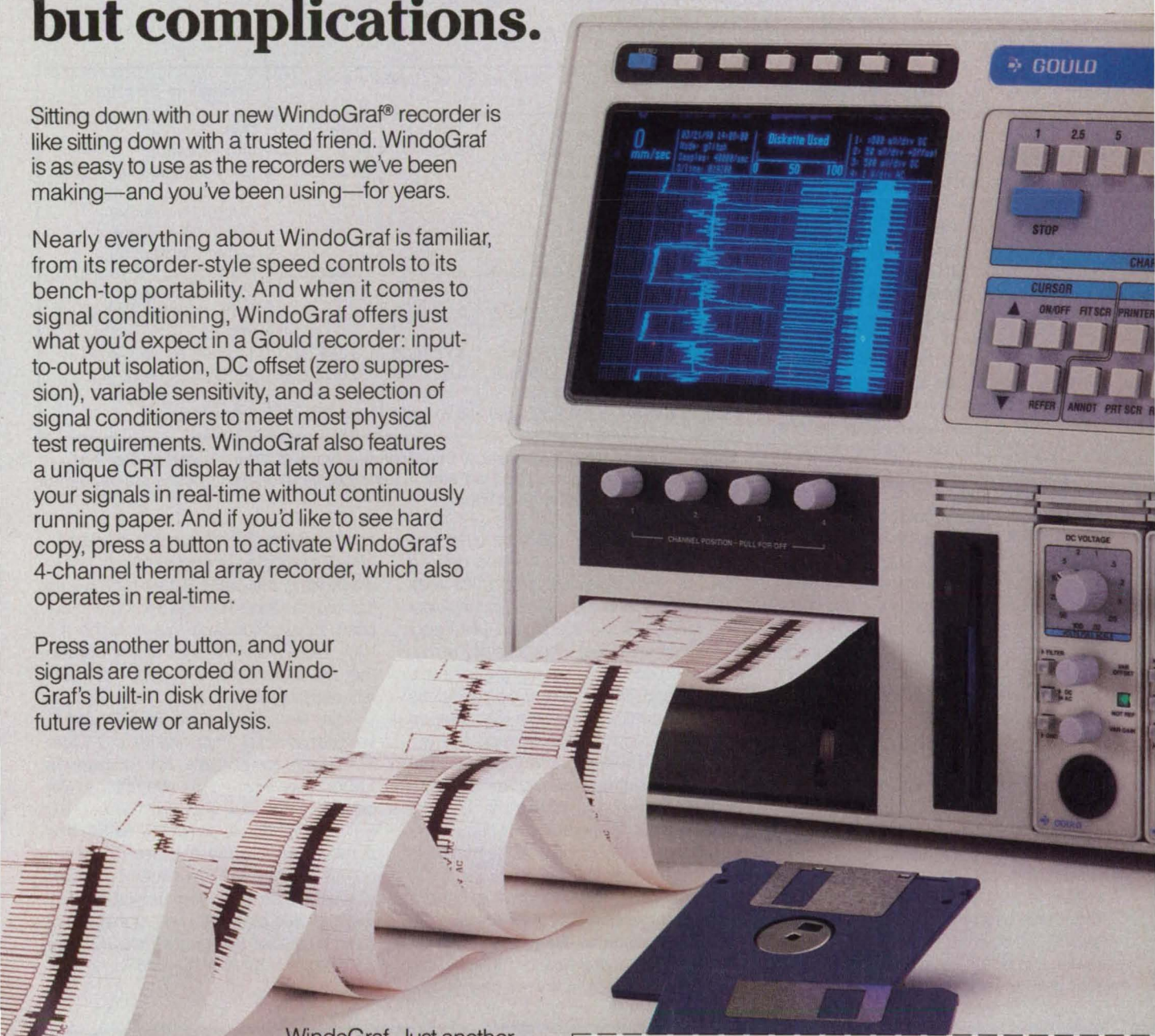


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# SNS Heterojunctions With New Combinations of Materials

Epitaxial heterojunctions would be formed between high-temperature superconductors and either oxide semiconductors or metals.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

New combinations of materials have been proposed for superconductor/normal-metal/ superconductor (SNS) heterojunctions in low-temperature electronic devices such as fast switches, magnetometers, and mixers. An SNS junction as proposed would be formed by epitaxial deposition of a first layer composed of high-temperature-superconducting oxide, a second layer composed of a semiconducting or metallic oxide, and a third layer composed of a high-temperature-superconducting oxide.

The SNS concept offers an appealing alternative to other three-layer heterojunction (e.g., superconductor/insulator/superconductor) concepts in that the physical principles of operation permit SNS devices to have thicker barrier layers and, therefore, to be fabricated more easily. Heretofore, the fabrication of SNS devices with high temperature superconductors has been inhibited partly by the high chemical reactivity between the superconducting materials and the common metals and semiconductors: typically, the metal partly reduces the superconducting oxide, thereby destroying the superconductivity in the region near the superconductor/metal interface. However, even in a case in which the metal (e.g., gold) does not react strongly with the superconducting oxide, the crystal lattices of the metal and the superconducting oxide typically do not match sufficiently to enable epitaxial growth.

The proposed combinations of materials are intended to provide the requisite low chemical reactivity and matching of crystal lattices at temperatures ranging from those used in depositing the layers (> 700 °C) down to those used in operation (~ −200 °C). The materials for a given SNS device would probably be selected from a list of oxides that have been tentatively identified as having the desired physical and chemical properties (see table). Considerations involved in the selection include those mentioned previously plus (1) the electrical properties of the materials, (2) compatibility with regard to oxidizing deposition or annealing conditions (for the growth of hole-type high-temperature superconductors) or reducing deposition or annealing conditions (for the growth of electron-type high-temperature superconductors), (3) phase changes that affect crystalline structures at various temperatures, and (4) stability of the materials at growth temperatures.

| Material | Parameters of Crystal Lattice, *R* | | | Crystalline Structure |
|---|---|---|---|---|
| | *a* | *b* | *c* | |
| $YBa_2Cu_3O_7$ | 3.82 | 3.89 | 11.68 | Orthorhombic |
| $Bi_2Sr_2CaCu_2O_{8+x}$ | 3.83 | 3.83 | 30.8 | Orthorhombic |
| $Tl_2Ba_2CaCu_2O_{8+x}$ | 3.855 | — | 29.35 | Body-Centered Tetragonal |
| $Nd_{1.85}Ce_{0.15}CuO_{4-x}$ | 3.95 | — | 12.1 | Body-Centered Tetragonal |
| $LaTiO_3$ | 3.934 | — | — | Cubic (Perovskite) |
| $CaVO_3$ | 3.767 | — | — | Cubic (Perovskite) |
| $SrVO_3$ | 3.838 | — | — | Cubic (Perovskite) |
| $WO_3$ | 3.65 (*a*/2) | 3.77 (*b*/2) | 3.844 (*c*/2) | Monoclinic, (17 to 320 °C) (Distorted $ReO_3$) |
| | 3.69 (*a*/2) | 3.77 (*b*/2) | 3.89 | Orthorhombic (320 to 720 °C |
| | 3.65 (*a*/2) | 3.76 (*b*/2) | 3.845 (*c*/2) | Triclinic (17 to −40 °C) |
| | 3.69 (*a*/2) | 3.69 (*b*/2) | 3.835 (*c*/2) | Triclinic (< −40 °C) |
| $Y_{0.09}WO_3$ | 3.800 | — | — | Cubic |
| $Ca_{0.02}WO_3$ | 3.67 (*a*/2) | 3.71 (*b*/2) | 3.84 | Orthorhombic |

These **Cuprate High-Temperature Superconductors** and other metal oxides that are variously semiconducting and metallic in their electrical characteristics are candidate materials for SNS heterojunctions.

In preliminary experiments, thin films of $WO_3$ were deposited by laser ablation onto $SrTiO_3$ substrates. Deposition in an oxidizing atmosphere resulted in fully oxidized $WO_3$ films, which were pale yellow and insulating. Deposition in a vacuum (in effect, a reducing atmosphere) resulted in black films that behaved as narrow-gap semiconductors. The first attempts to deposit superconducting thin films on the $WO_3$ films were not successful, but further experimentation with deposition conditions is planned.

*This work was done by Richard P. Vasquez, Brian D. Hunt, and Marc C. Foote of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 84 on the TSP Request Card.*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 20]. Refer to NPO-18483.*

# Circuits Protect Against Incorrect Power Connections

Simple circuits prevent the application of incorrectly polarized or excessive voltages.

*Lewis Research Center, Cleveland, Ohio*

Simple, relatively inexpensive auxiliary circuits can be connected temporarily or permanently at the power-connecting terminals of more-complicated and expensive main electronic equipment to protect that equipment against incorrectly polarized or excessive supply voltages. The circuits were devised to protect electrical and electronic equipment that is to be installed in spacecraft and that is subjected to a variety of tests in different facilities prior to installation. The basic concept of these protective circuits can also be applied easily to many kinds of electrical and electronic equipment that must be protected against incorrect power connections.

In the original spacecraft application, some tests of the main electrical and elec-

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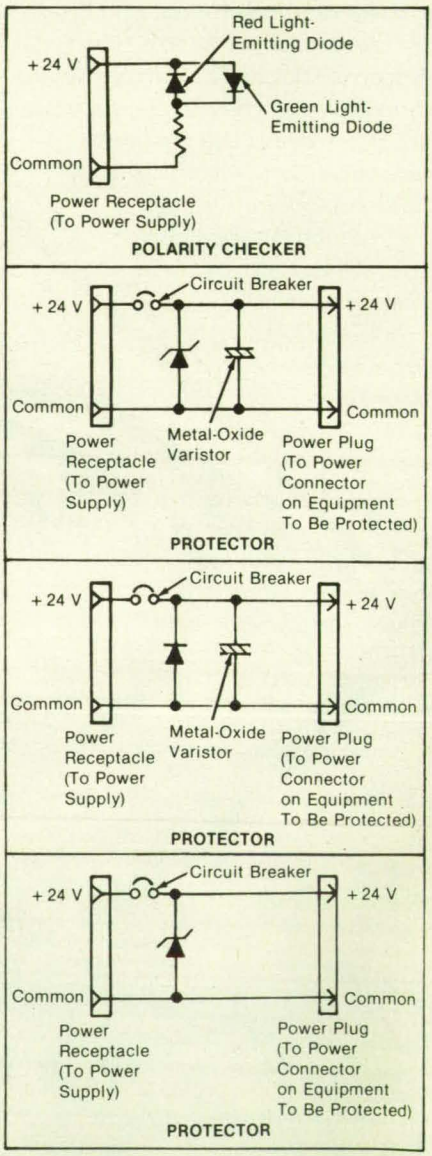
tronic equipment involve the use of other than the standard power supply and/or wiring harness, thereby introducing the possibility of miswiring. Where miswiring results in the application of excessive or reverse-polarity voltage, the equipment can be damaged, and/or fuses built into the equipment can be blown. In both cases, repairs are necessary. The protective circuits can eliminate these adverse consequences of miswiring.

In a spacecraft or similar application, the protective circuits would be used during initial "power-up" tests. After proper polarity and operation had been confirmed, the protective circuits would be removed for formal tests of function and performance: this would be done to ensure that the equipment works properly without the protective circuits. The protective circuits would then be reinstalled and would remain attached to the power connectors of the equipment throughout the remaining tests of the equipment. Immediately prior to shipping the equipment for installation in spacecraft, tests to confirm the adequacy of function and performance would be repeated without the protective circuits.

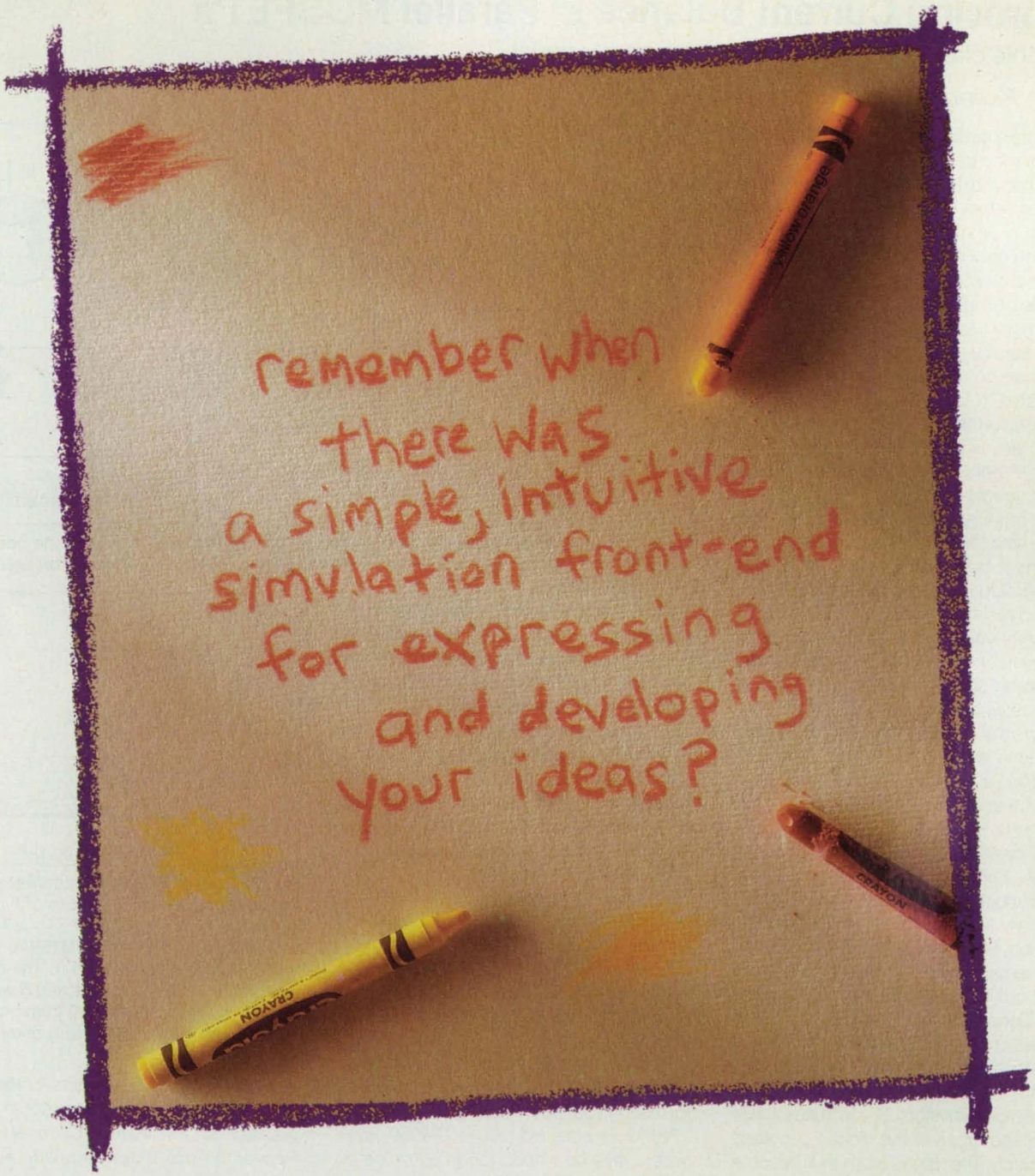
The first of the protective circuits shown in the figure is a simple polarity indicator. It is connected to the power-supply cable to determine the polarity of the supply voltage before the cable is connected to the equipment. A green or a red light-emitting diode in this circuit becomes illuminated, depending on whether the polarity is proper or reversed, respectively.

The other circuits protect against both overvoltage and reverse polarity in various ways. In each circuit, the diode prevents a reverse-polarity supply potential from rising beyond about 0.7 V. In the event that the reverse voltage gives rise to a sufficiently high current, the circuit breaker is tripped, removing the voltage entirely from the equipment. In the second and fourth circuits, Zener diodes protect against overvoltage. In the second and third circuits, metal-oxide varistors protect against overvoltage surges.

*This work was done by Richard Delombard of* **Lewis Research Center.** *No further documentation is available.*
*LEW-15294*




These **Simple Circuits** can be installed at the power terminals of more-complicated electrical and electronic equipment to protect against incorrect polarity and overvoltage.

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# Improving Current Balance in Parallel MOSFET's

A simple circuit makes currents more nearly equal.

*Lewis Research Center, Cleveland, Ohio*

A simple circuit improves the static current balance in two imperfectly matched power metal oxide semiconductor field-effect transistors (MOSFET's) that are connected in parallel and operated, from a common gate drive, in the active regions of their current-vs.-voltage characteristics. In some previous circuits, source-lead resistors have been used to balance currents. Small source-lead resistances balance large drain currents fairly well but become ineffective in balancing small drain currents. Conversely, large source-lead resistances are effective in balancing small drain currents but cannot support large drain currents.

The modified circuit (see Figure 1) includes small source-lead resistances, $R_s$, that tend to balance large currents. In addition, it includes two diodes and an adjustable-tap resistor $R$ that become relatively more influential at smaller drain currents. Acting in concert with $R_s$, the diodes and $R$ smoothly shift the current from paths of higher resistance to paths of lower resistance as the current increases. The effect of the shift is to reduce the unbalance by generating a difference between the gate-to-source potentials in the two MOSFET's.

At large currents (of the order of amperes), most of each drain current ($I_1$ or $I_2$) emerges from the corresponding drain and flows through the corresponding $R_s$, which is typically a fraction of an ohm. Under this condition, the voltage drop in each diode, which remains below 1 V, is relatively small and about equal to the drop in the other diode. Consequently, $R$ has little effect, and the resistors $R_s$ approximately balance the currents in the usual way.

As the drain currents decrease, the voltages across resistors $R_s$ decrease while the voltage drops in the diodes decrease less sharply. The diodes drops thus become significant compared to the voltage drops in each side of $R$. Thus, as the currents decrease to values at which the resistors $R_s$ become ineffective, the resistor $R$ starts to provide the differential voltage drop needed to help restore balance.

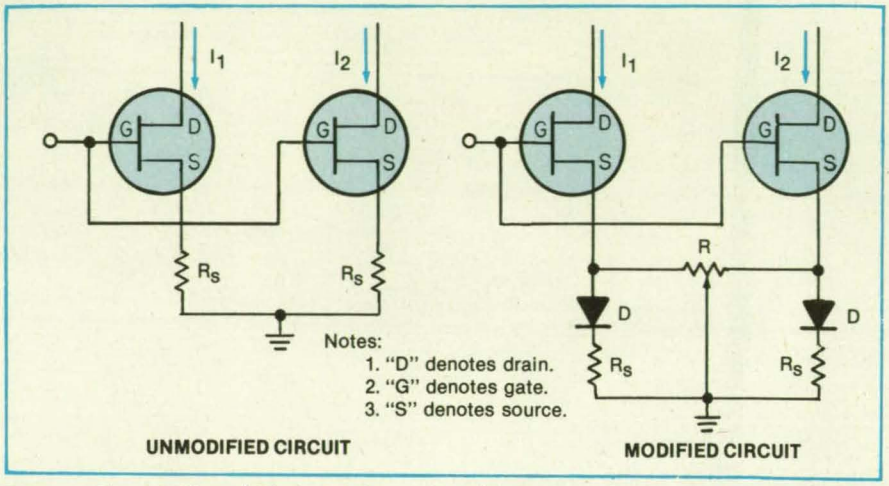


Figure 1. The **Addition of Diodes and an Adjustable-Tap Resistor** increases the operating range over which drain currents in two unmatched power MOSFET's can be brought more nearly into balance.

In an experiment, the current unbalance, $(I_2-I_1)/(I_2+I_1)$ was measured in two circuits: a conventional one with source-lead resistors only, and one with the diodes and an adjustable-tap resistor added. As shown in Figure 2, the modified circuit exhibited less current imbalance.

*This work was done by Janis M. Niedra of Sverdrup Corp. for* **Lewis Research Center**. *Further information may be found in NASA CR-180902 [N89-26150], "Paralleling Power MOSFET's in Their Active Region: Extended Range of Passively Forced Current Sharing."*

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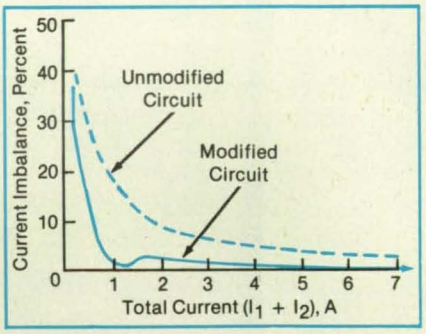


Figure 2. The **Relative Unbalance** was measured in circuits like those of Figure 1. In both circuits, the MOSFET's were the same two unmatched MTM15N40 power MOSFET's, and $R_s$ was 0.5 Ω. The diodes were 1N1201 silicon devices, and $R$ was 2 Ω. The tap in $R$ was set at 0.8 Ω from one end, corresponding to a subjectively determined optimum.

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center [see page 20]. Refer to LEW-14886.*

# Superconductive Coplanar-Waveguide Filters

Insertion loss is less than that of a similar filter made with copper.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Coplanar-waveguide microwave low-pass filters based on thin films of the high-critical-temperature superconductor $YBa_2Cu_3O_7$ have been built and tested. Devices like these are expected to become increasingly common because superconductivity offers the potential to reduce signal losses and because $YBa_2Cu_3O_7$ can be made superconductive economically and conveniently by cooling it in liquid nitrogen to 77 K.

The experimental superconductive filters are designed to provide a passband of 0 to 9.5 GHz. Their dimensions are suitable for microwave integrated circuits and are chosen to provide a fairly stringent test of the usefulness and practicality of the design and of the method of fabrication. Each filter (see Figure 1) includes tapered transitions between microstrip and coplanar-waveguide configurations at the input and output terminals, coplanar-waveguide transmission lines of 50-Ω impedance near these transitions, and alternating high- and low-impedance sections of coplanar-waveguide transmission line along the intervening transmission path.

The fabrication of each filter began with the deposition of 0.5-μm-thick film of $YBa_2Cu_3O_7$ by laser ablation onto the top surface of an $LaAlO_3$ substrate 0.5 mm thick. By a sequence of steps that involved sputter deposition of gold, photolithography, and argon-ion milling of the $YBa_2Cu_3O_7$, the superconducting film was patterned and gold pads were deposited on the

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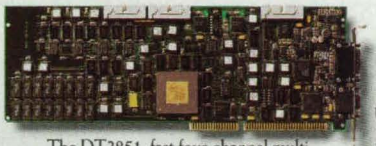

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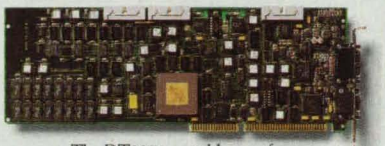

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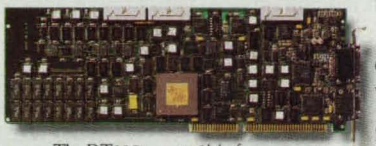

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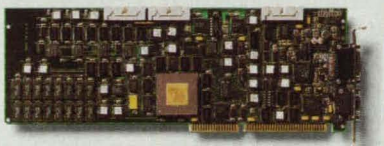
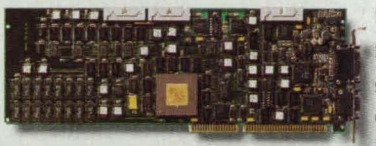
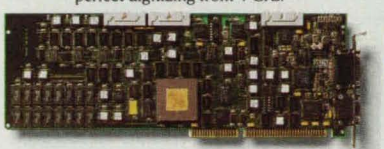


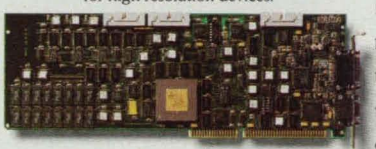
The DT3851: special circuitry for perfect digitizing from VCRs.



The DT3851: 1K x 1K input for high resolution devices.



The DT3851: precise image digitization for microscopy.



The DT3851: integrated graphics for one-monitor systems.

As you can plainly see, our new DT3851 image processing board is a multi-talented performer.

That's why anyone who knows image processing will agree that the DT3851 Series is far and away the best choice for the vast majority of applications. This Jack of all trades masters any task, because it has features, flexibility and software support that equal or exceed your single-purpose boards.

The DT3851 combines the industry's most flexible and precise frame grabber with a very powerful display controller. It can capture images from any input device as precisely as needed – up to 1,024 x 1,024 resolution.

DT-Open Layers FOR MICROSOFT® WINDOWS™

What's more the DT3851 can either display images on a single monitor, integrated with Windows graphics, or be used in a traditional dual monitor configuration.

With this versatile board, input parameters are software-programmable. Display parameters are software-selectable

- Displays live video in a window
- Gain, offset, and reference adjustment
- Perfect synchronization to VCRs in pause mode
- Lowest pixel jitter of any PC-based system
- Supports standard or nonstandard input devices to 1K x 1K
- Displays multiple images anywhere on the screen
- Accelerates Windows graphics with onboard TMS34020 processor
- DT-Connect® interface

up to 1,024 x 768, in interlaced or non-interlaced format.

The DT3851 comes with a free Windows DLL and a free DOS library that control all board functions and perform frame averaging. It is supported by our GLOBAL LAB® *Image* 2.0 application and library software. That means it also conforms to DT-Open Layers,™ the Windows standard, so you know your software investment is protected.

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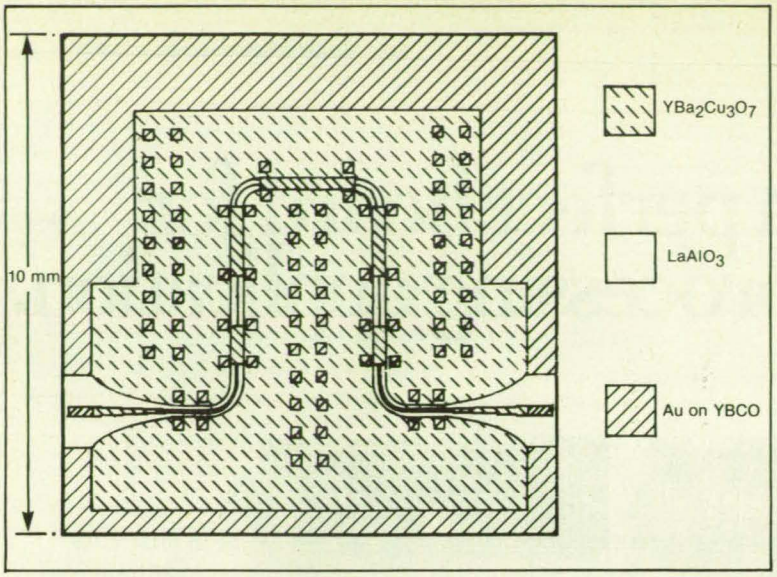


Figure 1. This **Coplanar-Waveguide Low-Pass Filter** is designed to test the practicality of making such devices with the high-critical-temperature superconductor $YBa_2Cu_3O_7$.

$YBa_2Cu_3O_7$. Some of these pads accommodate gold-wire-bond connections to 50-Ω microstrips that, in turn, connect the input, output, and test terminals to coaxial fittings for connection to the testing circuitry. Other gold pads accommodate connections to coplanar grounds to prevent undesired propagation modes at steps and bends in the coplanar waveguide. The bottom surface of the substrate was covered by layers of niobium and gold. For comparison, a filter of similar dimensions was fabricated, using a copper film 1.0 $\mu$m thick in place of $YBa_2Cu_3O_7$.

Four filters made with $YBa_2Cu_3O_7$ and the one made with Cu were packaged for measurement of their microwave losses and immersed in liquid nitrogen for testing at 77 K. As expected, the insertion losses of the four $YBa_2Cu_3O_7$ filters were less than that of the Cu filter. The cutoff frequencies and passband responses of the four $YBa_2Cu_3O_7$ filters differed somewhat from unit to unit; the differences are attributed to variations in critical temperature, magnetic field penetration depth, film thickness, and linewidth, which can affect the internal inductance of the film significantly since 77 K is close to the critical temperature of 83 to 88 K measured in these filters after patterning.

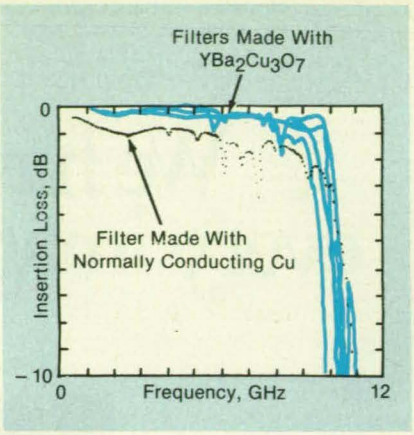


Figure 2. The **Insertion Losses of Filters** like the one shown in Figure 1 were measured at a temperature of 77 K.

*This work was done by Wilbert Chew, Louis J. Bajuk, Thomas W. Cooley, Marc C. Foote, Brian D. Hunt, Daniel L. Rascoe, and Abraham L. Riley of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 91 on the TSP Request Card.*
*NPO-18424*

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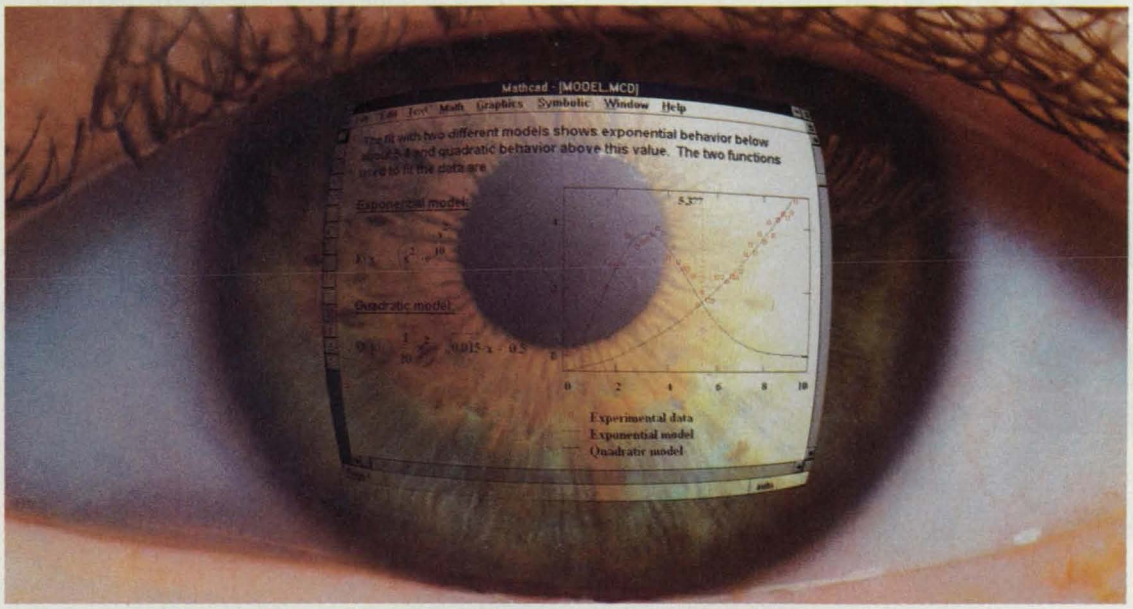


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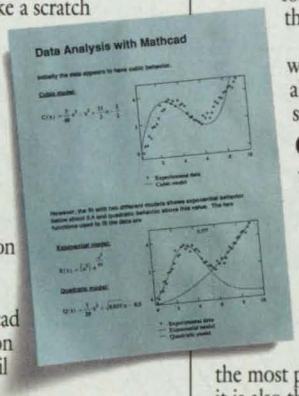


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**For More Information Circle No. 421**

# Optical Link for Readout From Focal-Plane Array

The outputs of photodetectors would modulate a beam of light.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

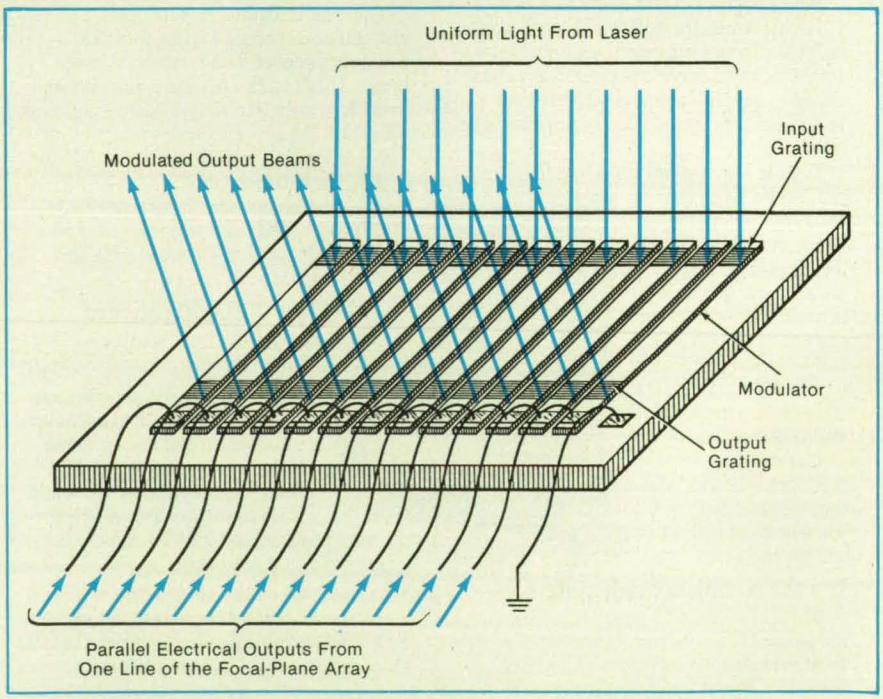
A proposed optical link would carry analog readout signals from photodetectors in a focal-plane array to external signal-processing circuitry. Typically, the focal-plane array would comprise infrared detectors and would be maintained at low temperature in a cryogenic apparatus. Like optical links in general, this one is expected to be insensitive to electromagnetic interference at suboptical frequencies. In comparison with electronic and some other proposed optical links, this one would impose a smaller heat load on the cryogenic apparatus because it would not include a high-power electronic amplifier or laser transmitter within the cold chamber.

The figure illustrates a version of the proposed optical link, through which the image would be read out one line at a time. A linear array of optoelectronic modulators would be mounted in the cold chamber along with the focal-plane array. The electrical outputs of the photodetectors would be fed through multiplexer switches and low-voltage amplifiers to the modulators, such that the electrical signal applied to each modulator would represent the illumination on one of the photodetectors in the momentarily selected line of the image.

Each modulator would be a multiple-quantum-well laserlike device — for example, made of $In_xGa_{1-x}As/GaAs$ — and would include an etched input diffraction grating at one end and similar output grating at the other end. A diode laser located in the warm external environment would be spectrally matched to the modulators. Light from this laser would be focused on the input gratings.

The light transmitted through each modulator would be attenuated via the quantum-confined Stark effect to a degree that would depend on the applied voltage and, therefore, on the illumination of the corresponding photodetector. The modulated light would be coupled through the output gratings to a linear array of external photodetectors — for example, made of silicon — that would be part of the processing circuitry in the warm environment.

*This work was done by Eric R. Fossum, Anders G. Larsson, and Joseph Maserjian of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 29 on the TSP Request Card.*
*NPO-18481*




The **Uniform Input Beam** would be converted to a number of modulated output beams that would be focused onto an equal number of photodetectors in a linear array.

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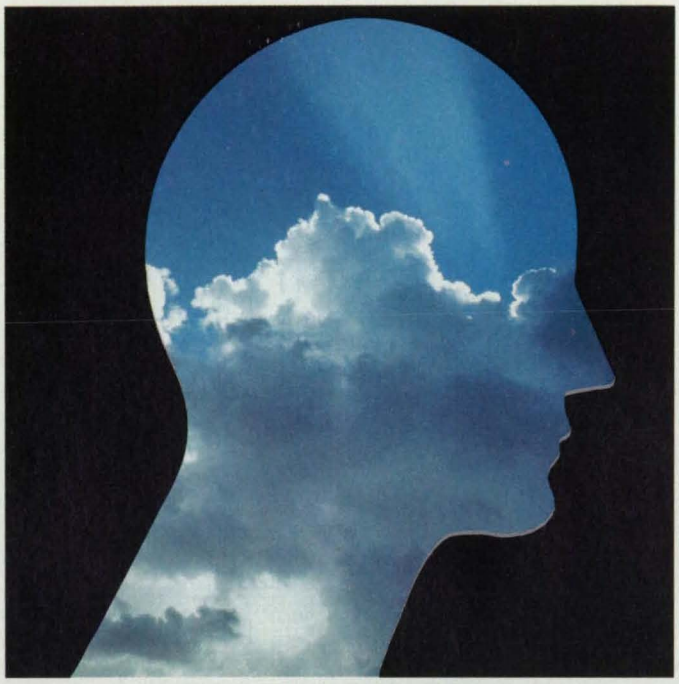

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Since then, the Techron spark of ingenuity has helped pave numerous inroads to a better way of life. After MRI applications came many exciting new fields of research. Most recently, research to make other medical procedures safer and less painful. The clean, steady reliability of Techron power is there.

Techron's influence has been truly far-reaching. In chemical analysis, expanding the ways X-rays create images. Guiding new ways of thinking in space exploration. Powering oil exploration. Vibration test systems. Quality assurance testing for transformers, capacitors and cable harnesses. Recycling methods. Radar installations. Automotive research for safer vehicles of the future. Safer mining by underground signalling. Particle acceleration studies. Noise-reduction research. Distance relay safety testing for sensing faults in high-tension wires. And currently, testing and setting the standards for the Electrical Power Regulatory Institute.

It started with a product: Strong, clean, reliable power amplifiers. But it grew to fuel a generation of strong new ideas that not only are improving our lives today, but building a better future. We're proud to be a part of it. And we're committed to staying here. Right behind your greatest ideas.

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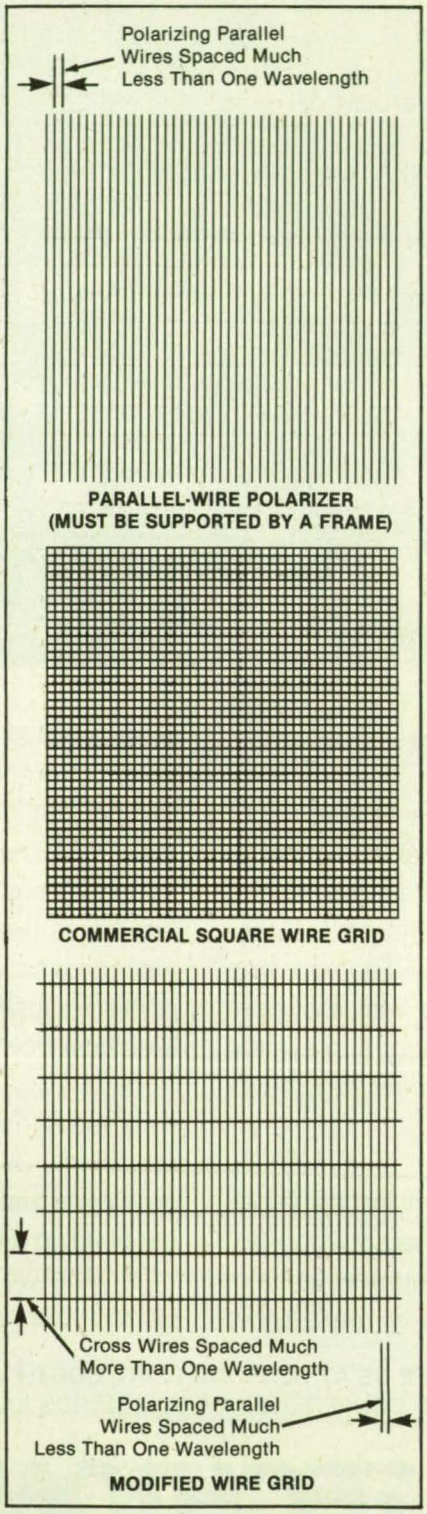
**For More Information Circle No. 671**

# Photofabricated Wire-Grid Polarizers

Parallel-wire polarizers for submillimeter wavelengths can be made without dielectric supports.

*NASA's Jet Propulsion Laboratory, Pasadena, California*




The **Modified Wire Grid** includes supporting cross wires like those of the commercial square wire grid, but they are placed farther apart.

Freestanding metallic grids for use as polarizers for electromagnetic radiation at millimeter and submillimeter wavelengths would be made by simple modification of the designs of freestanding square- and nearly-square-cell metallic grids, according to a proposal. The commercial process for the fabrication of such grids involves a combination of photolithography and electrodeposition.

A grid of parallel metal wires spaced much less than a wavelength reflects most of the radiation electrically polarized parallel to the wires and passes much of the radiation electrically polarized perpendicular to the wires. Such grids have been used as polarizers for many years. In a typical grid suitable for a submillimeter wavelength, the thickness and spacing of the wires must be of the order of 25 $\mu$m or less — too fine to fabricate the grid by winding tensioned wire on a frame. One could provide the necessary mechanical reinforcement by photofabricating the grid on a dielectric sheet, but the dielectric material would add reflection and absorption losses.

The figure shows a parallel-wire-grid polarizer, a commercial square wire grid with a spacing equal to that of the polarizer, and the modified wire-grid polarizer. As in the square grid, the cross wires in the modified grid provide mechanical support, but the distance between the cross wires in the modified grid is made much greater than one wavelength so that the cross wires have little effect on the polarizing characteristics of the grid.

The modified-grid mechanical structure has been verified by custom-fabricating a grid of copper 0.0015 in. (about 38 $\mu$m) thick with parallel polarizing wires spaced 0.006 in. (about 150 $\mu$m) apart and a cross-wire spacing of 0.2 in. (about 5 mm). The grid was flat and covered an aperture 3 in. (about 7.6 cm) wide. It should be possible to fabricate grids commercially for frequencies up to several terahertz.

*This work was done by Peter H. Siegel and Robert J. Dengler of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 33 on the TSP Request Card.*
*NPO-18272*

## 300 WATT DC SUPPLIES
### *75 kV...3.5 in....18 lbs.*

The ER Series features 300 watt capability with output ranges from 0 to 1 kV through 0 to 75 kV. Panel height is only 3.5 inches and weight less than 18 lbs. Automatic crossover from constant-voltage to constant-current regulation protects against overloads, arcs, and short circuits. The ER Series features local as well as full remote operation, including control and monitoring, TTL enable/disable, and safety interlock terminals.
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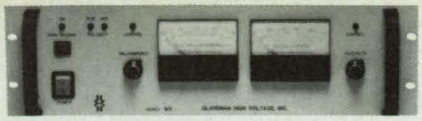
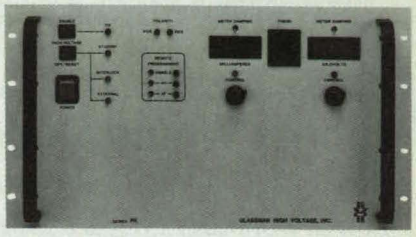


## UP TO 125 kV DC...
### *250 watts...5.25 in.*

The Glassman WR Series 250 W regulated power supplies complement the ER Series by adding DC output ranges from 0 to 85 kV through 0 to 125 kV. Panel height is 5.25″ and weight less than 40 lbs. Available with analog or digital voltage and current displays or with a blank panel for OEM/system applications, the WR Series is adaptable to most operating environments.
***Glassman High Voltage***

## HV POWER SUPPLIES
### *Up to 500 kV and 15 kW*

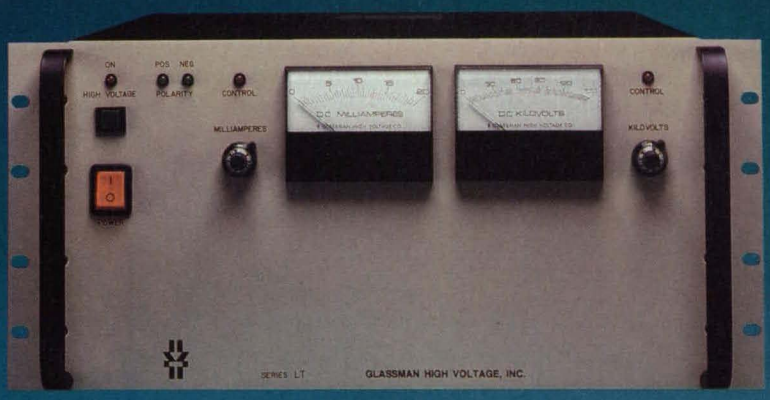


Series PK regulated high voltage power supplies cover DC output ranges from 0 to 3 kV through 0 to 500 kV with 4, 8, 12, or 15 kW maximum power. For models up to 125 kV, the power supplies are totally enclosed in a 19-inch rack; above 125 kV, the high voltage multipliers are housed in an open stack. Models are available with positive, negative, or reversible polarity.

Features include pulse-width modulation for low parts count and high efficiency, low stored energy for safety, air insulation of HV components for serviceability and low weight, and automatic crossover from constant-voltage to constant-current regulation for protection from overloads, arcs, and short circuits.

Local operation is simplified by the use of dual voltage and current digital panel meters, with selectable damping, and dual bargraph analog displays, together with full status indicators. External monitoring/control and an intelligent interlock system are standard.
***Glassman High Voltage***

# 125 kV...2 kW...8.75 IN. WOW!




Imagine. Series LT models ranging from 0 to 1 kV through 0 to 125 kV, with output power to 2 kW, and all packaged in a 8.75″ rack height weighing less than 47 lbs! Your choice of analog or digital displays, or a blank panel for system use. Local and remote control and monitoring are all standard.

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- Voltage regulation better than 0.005%
- Ripple less than 0.03%
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- Choice of positive, negative, or reversible polarity
- 220/240 V single-phase input

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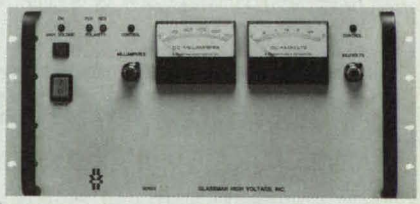


## DC SUPPLY TO 125 kV...
### *with 1 kW plus*

LX Series is available with DC ranges from 0 to 1 kV through 0 to 125 kV, all from a 120 V single-phase input. Rated 1 kW at full voltage, the LX provides currents equivalent to a 2 kW supply up to 50% of rated voltage. Panel height is only 8.75 inches and weight less than 47 lbs. Positive, negative, or reversible models. Normally supplied with dual analog voltage and current meters, the LX Series can be ordered with dual digital meters or with a blank panel for OEM/system applications.
***Glassman High Voltage***

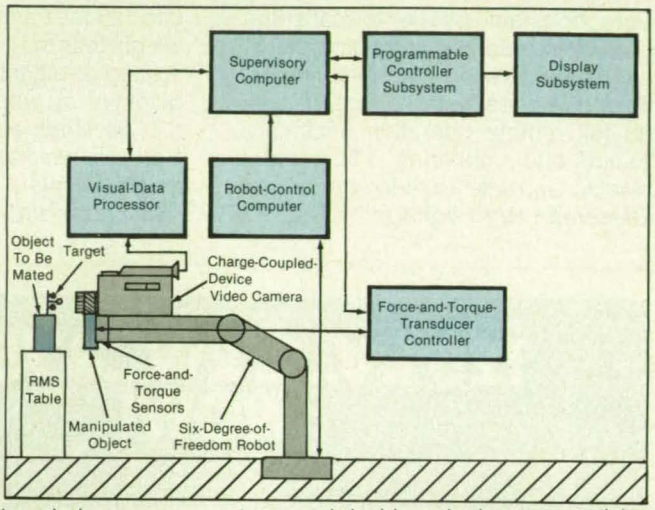
# Robots Would Couple and Uncouple Fluid and Electrical Lines

Sensing and control systems would include vision, force, and torque subsystems.

*John F. Kennedy Space Center, Florida*

Robots that are being developed at Kennedy Space Center would make and break connections between umbilical plates (plate-mounted assemblies of fluid and electrical lines and their connectors) and mating connectors on rockets about to be launched. These robots would enhance safety by making it possible to couple and uncouple the umbilical plates quickly, without exposing human technicians to the hazards of leaking fuels and oxidizers. They would also significantly reduce the time now spent to manually connect these umbilicals. Robots based on similar principles could be used in refueling of (1) the National Aero-Space Plane (NASP) and (2) satellites and orbital transfer vehicles in space.

Recent development efforts have been directed toward integration of a commercial robot and its control subsystem with (1) a force-and-torque-sensing and -control subsystem and (2) a vision subsystem for noncontact tracking, all under the control of (3) a common supervisory computer (see figure). The basic idea is to make the robot use the force, torque, and visual-tracking information to adjust its movements in six degrees of freedom (three perpendicular translations, roll, pitch, and yaw) as the robot performs the commanded manipulation while one or more object(s) in the scene move(s); e.g., the spacecraft sways in the wind.




The **Robotic System** includes an advanced vision system that computes the position and orientation of the manipulated object relative to the target.

The vision subsystem is the most novel component of the overall robotic system. It contains circuit boards that execute built-in image-processing algorithms that can analyze as many as 250 objects in the scene at the camera-frame rate. These circuit boards and algorithms are used in conjunction with other robotic software developed by NASA/AAI (Adaptive Automation, Inc.) that calculates the set of six continuously varying coordinates of robot motion at each successive interval of 33 ms.

The supervisory computer receives data from the vision and force-and-torque systems and decides whether to use vision tracking (e.g., during initial approach or final retreat) or force-and-torque tracking (e.g., during contact between the objects to be coupled or uncoupled). During force-and-torque tracking, the robot is generally commanded to move along computed vectors to relieve excessive contact forces while moving toward or maintaining the specified position and orientation.

*This work was done by Eduardo Lopez del Castillo, Virgil Davis, Bob Ferguson, and Garland Reichle of* **Kennedy Space Center**. *For further information, Circle 14 on the TSP Request Card.* *KSC-11467*

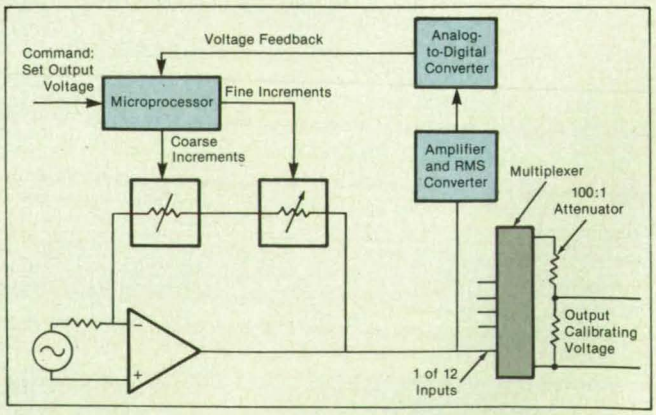
# Generating Multiple Calibrating Voltages Simultaneously

Twelve different voltages on fifty channels can be generated by remote control.

*Marshall Space Flight Center, Alabama*

A calibrating unit that contains a signal generator controlled by a microprocessor puts out ac signals of known voltages on fifty channels simultaneously. The signals are used to calibrate high-frequency tape recorder channels for multiple, ac-coupled strain gauges simultaneously.

The calibrating voltage required on each tape channel is determined by a remote computer, and the corresponding data and commands are transmitted to the microprocessor via modems. The microprocessor in turn, causes the output voltages in the eight signal-generator channels to be set at the commanded levels and causes each of these voltages to be multiplexed to its commanded tape channel(s). The principal virtue of the microprocessor-controlled calibrating unit is that it saves time; in the original application for which the unit was designed, two technicians recording the appropriate signals manually, one channel at a time, took about 3 hours to perform calibration and setup. With the help of the calibrating unit, one technician can perform calibration and setup in 20 minutes.




The **Microprocessor Sets the Output Voltage** to the commanded level by use of a combination of analog and digital feedback.

The calibrating signal in each channel can be set at any level from 1 to 20 mV

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VRK Rack-Mount PC's come in heavy-duty metal cases for EMI/RFI protection.

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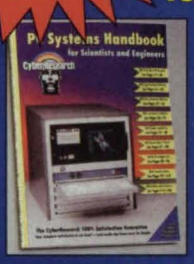


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root mean square (rms) in increments of 14.3 $\mu$V, by means of the following feedback-control scheme (see figure). Each of the eight programmable voltage levels are accomplished by using microprocessor-controlled stepper potentiometers as feedback on an operational amplifier. Two different potentiometer ranges are used to provide a coarse and a fine increment. The operational amplifier is excited with a sinusoidal voltage of 1 kHz, 6 V (peak to peak), and the coarse increment is set initially on command to obtain approximately the desired voltage. The ac output of the voltage divider is amplified, and a dc signal indicative of its value is generated. The microprocessor uses a 16-bit analog-to-digital converter to read the rms value and adjusts the fine increment until the desired level is reached. At this stage, the fine increments are 1.43 mV.

In addition to the eight channels that are programmable as indicated above, there are four channels in which the levels can be set manually by use of pushbutton switches connected to potentiometers. All twelve voltage levels are connected to each of the fifty analog multiplexers. Each multiplexer drives a 100-k$\Omega$ resistive attenuator, yielding the final output voltage in increments of 14.3 $\mu$V.

*This work was done by Lionel J. Dutreix of Rockwell International Corp. for* **Marshall Space Flight Center**. *For further information, Circle 18 on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-29830.*

# Scanning-Pencil-Beam Radar Scatterometer

Accuracy and coverage would exceed those of a fan-beam scatterometer.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

The SCANSCAT is a conceptual scanning radar scatterometer that would be placed in a nearly polar orbit around the Earth at an altitude of 705 km aboard Spacecraft B of NASA's Earth Observing System. The SCANSCAT would measure radar backscattering from the surface of the ocean. The measurement data would be processed on the ground into normalized radar-backscattering cross sections that would, in turn, be processed into velocities of winds near the surface of the ocean by use of an empirical mathematical model of the relationship between the normalized backscattering cross section, the wind vector at the scanned spot, and the angle of incidence and azimuth angle of the radar beam.

The SCANSCAT would generate two pencil beams that would be scanned conically about the nadir at a rate of about 16 rpm. The inner beam would have an angle of incidence of 41°, tracing out a helical pattern of overlapping near-circles on the surface that would define a swath about 1,000 km wide. The outer beam would have an angle of incidence of 54° and would trace out a similar pattern, defining a swath 1,600 km wide.

This scanning plan would yield four measurements at each surface point in the inner scan, corresponding to two azimuth angles (one for each of two positions along the trajectory) for the inner beam and two azimuth angles (one for each of two other positions along the trajectory) for the outer beam. For each surface point within the outer scan but outside the inner scan, there would be only two measurements, because this region would be reached by the outer beam only. Modified versions of this scanning plan might also be useful in other applications; for example, laser inspection of surface finishes on machined parts.

The SCANSCAT would offer several advantages over the prior fan-beam radar scatterometers. The concentration of the transmitted power into the narrower pencil beam would result in higher signal-to-noise ratios; this would enhance the ability to measure wind velocities accurately, especially at low speeds, at which backscattering is low. Unlike a fan-beam scatterometer, which cannot scan within about 325 km on either side of the surface track of the spacecraft, the SCANSCAT would scan in a single wide, continuous swath. The SCANSCAT would also provide greater directional accuracy. Finally, because the SCANSCAT would use only horizontal polarization at only two angles of incidence, the model relationship between the normalized scattering cross section and the windspeed could be simplified (it would not be necessary to specify the model over the broad range of angles of incidence and both vertical and horizontal polarizations as it would be for a fan-beam scatterometer).

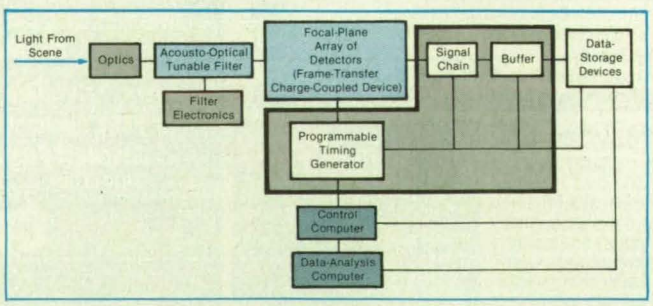
*This work was done by David G. Long, Michael H. Freilich, Daniel F. Leotta, and Don E. Noon of* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 105 on the TSP Request Card.*
*NPO-18300*

# Programmable Hyperspectral Imaging Mapper

Features would include spectrally agile filters and processing on the focal-plane array.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

The programmable hyperspectral imaging mapper (see figure) (PHIMAP) is a conceptual generic advanced spectral imaging system that would scan a swath along a ground track from an airplane or a spacecraft in orbit. The PHIMAP is based partly on prior spectral imagers and partly on advanced concepts, not yet fully developed, of spectrally agile filters and processing of imagery on focal-plane arrays. The PHIMAP would provide both high spatial resolution and a large number (typically > 100) of spectral channels. It could be programmed to trade spectral resolution and spectral coverage flexibly against signal-to-noise ratio to optimize the utility of image data from scenes of spectrally and spatially varying brightness.




The **Programmable Hyperspectral Imaging Mapper** would feature a spectrally agile filter (the acousto-optical tunable filter), which could be tuned in real time in synchronism with an on-array-processing scheme to trade spectral resolution against signal-to-noise ratio in response to spectrally and spatially varying brightness.

The PHIMAP would scan in "pushbroom" fashion as it moved along the ground track. A crosstrack line in the scene would be focused through a spectrally agile filter (an acousto-optical tunable filter) onto a focal-plane array containing $M$ columns in the cross-track direction and $N$ rows in the perpendicular direction. The spectrally agile filter would disperse the scene spectrally

along the $N$ rows, thereby defining a maximum of $N$ spectral channels. Thus, images of the same line at as many as $N$ different wavelengths could be acquired simultaneously. Of course, to obtain maximum resolution along the ground track, it would be necessary to transfer out the accumulated $M \times N$ image data in a frame period no longer than $\Delta T$, the time it takes the spacecraft or aircraft to move a distance equivalent to one picture element along the ground track.

In one mode of operation, the spectral passband would be changed each time the scene advanced by one picture element along the ground track. Up to $N$ spectral channels of data, each with a maximum exposure of $\Delta T$, could be acquired before the scene advanced the width of the frame. Cycling through the $N$ spectral channels would yield a series of contiguous frames in a continuous strip map along the ground track.

Because the acousto-optical filter would be electronically tunable, its dispersive characteristics could be altered in real time to apportion the $N$ rows among fewer spectral channels (at the extreme, to only one channel) and to add together the contributions of rows grouped together in the same channel. This would have an effect equivalent to multiplying the exposure time proportionally to the number of rows assigned to each channel, thus increasing the signal-to-noise ratio in the retained channel(s) at the expense of the deleted channel(s).

The focal-plane array would be a fairly conventional silicon-based frame-transfer charge-coupled device that would be operated in an unconventional manner. Contributions from different rows grouped into spectral channels would be added together by use of an on-array-processing scheme in which the image charges from each affected row would be accumulated in a nearby on-chip (but off-focal-plane) storage area during the required multiple-$\Delta T$ exposure time. At the conclusion of each such operation, frame-transfer and readout operations would take place; these operations would be synchronized with the changes of spectral bands.

*This work was done by James A. Cutts of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 88 on the TSP Request Card.*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 20]. Refer to NPO-17794.*



# Radar Altimetry for Topographical Mapping

Data on large areas could be acquired despite cloud cover.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Two altimeter concepts based on spaceborne synthetic-aperture radar (SAR) have been proposed to gather global, uniformly sampled, high-resolution, topographical data on land and ice. The wide swath and high pulse rate of SAR make it possible to acquire spatially contiguous data over large areas in a reasonable amount of time, and the time needed for altimetric processing of SAR data is considerably less than that needed to generate topographical maps from stereoscopic photographs. Furthermore, radar is less vulnerable to cloud cover and other weather conditions than the optical techniques are.

The conceptual designs of the two altime-

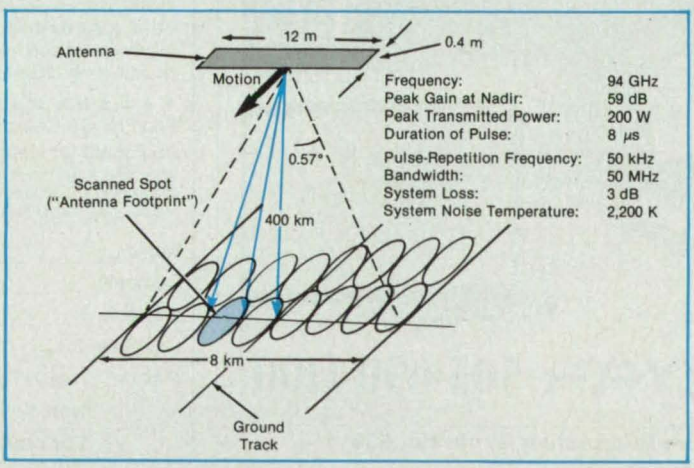



Figure 1. The **Scanning Synthetic-Aperture-Radar Altimeter** would acquire topographical data along a near-nadir swath, measuring altitude by the pulse-round-trip-time method.

ters reflect the intention to gather data from polar orbits at an altitude of about 400 km, but the principles of operation are also applicable to airborne radars. For these two approaches, good spatial resolution in the along-track direction is accomplished by the well-known SAR technique. One of the proposed altimeters, called the scanning synthetic-aperture-radar altimeter (SSARA), would include an antenna that would be electronically steered in the crosstrack direction. This system would use short pulses, measuring the altitude of the scanned spot by the conventional pulse-round-trip-time method. Figure 1 illustrates the geometric relationship between the antenna and scanning pattern of the SSARA and presents some tentative design parameters. This system would achieve horizontal and vertical resolutions of 105 and 3 m, respectively. The horizontal resolution of this design is limited by the antenna size in the cross-track dimension.

The second proposed altimeter concept, called the interferometric synthetic-aperture-radar altimeter (ISARA), can be used if a global altimetric data set of even finer spatial resolution is desired. This system would include two antennas separated by a fixed distance and aimed at a fixed cross-track slant from the nadir. Pulsed signals would be transmitted from one of the antennas, the echoes would be received by both antennas, and the phases of the echoes would be measured. The difference between the phases of the radar images recorded by the two antennas would be a function of the altitude of the reflecting surface and would be processed into altitude data by use of the applicable interferometric formulas. Using the configuration and design parameters shown in Figure 2, this system would achieve a horizontal resolution of about 30 m and a vertical resolution of about 3 m.

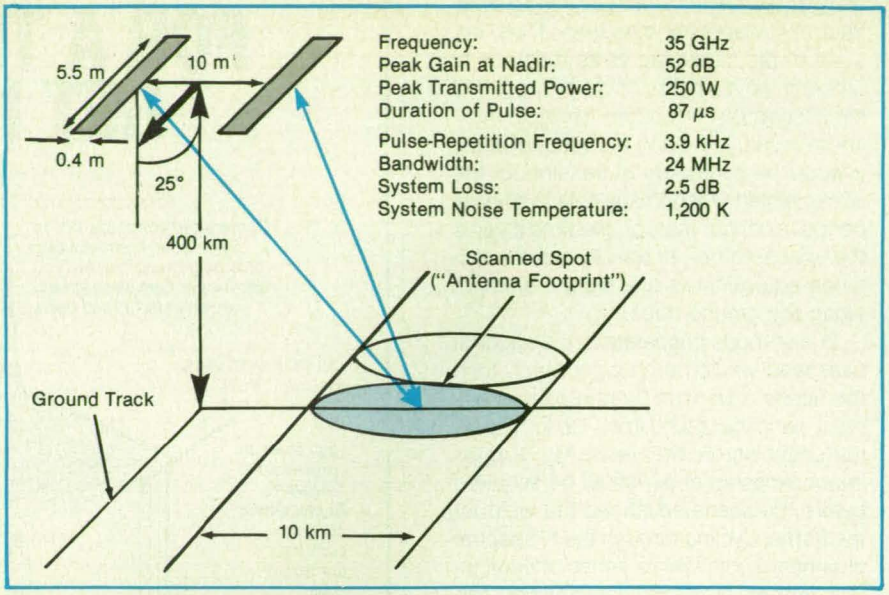



Figure 2. This **Interferometric Synthetic-Aperture-Radar Altimeter** would acquire topographical data from a swath on one side of the ground track. Interferometry would be used to determine altitude.

*This work was done by Eastwood Im of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 27 on the TSP Request Card.* *NPO-18254*

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**For More Information Circle No. 445**

# Reconfigurable Fuzzy Cell

A flexible sensor-signal-processing circuit would respond rapidly.

*Lyndon B. Johnson Space Center, Houston, Texas*

The reconfigurable fuzzy cell is a conceptual digital and analog electronic circuit that would preprocess raw sensor outputs in real time for use in an electronic control system based on fuzzy logic. This preprocessor is intended to relieve other data processors of the time-consuming computational task of converting every digitized sensor output into its grade of membership in a specified fuzzy set [e.g., a pressure measurement for which the grade of membership of the fuzzy set "high pressure" ranges from 0, indicating null membership (large leak), to 1, indicating full membership (no leak)]. By performing the conversion via hardware instead of software, the reconfigurable fuzzy cell would make possible higher throughput than is available in some prior fuzzy-logic systems in which the main computers perform the conversions of raw data to grades of membership via software.

Unlike the data-acquisition and -conversion hardware used to increase throughput in some other prior fuzzy-logic systems, the reconfigurable fuzzy cell would not have to be replaced to respond to changing acquisition membership functions and conversion requirements: it could, as its name suggests, be reconfigured (reprogrammed) during operation. In effect, it would act also as a real-time coprocessor, enabling the central fuzzy controller/processor (the main computer) to specialize in treating the converted data by use of fuzzy algorithms.

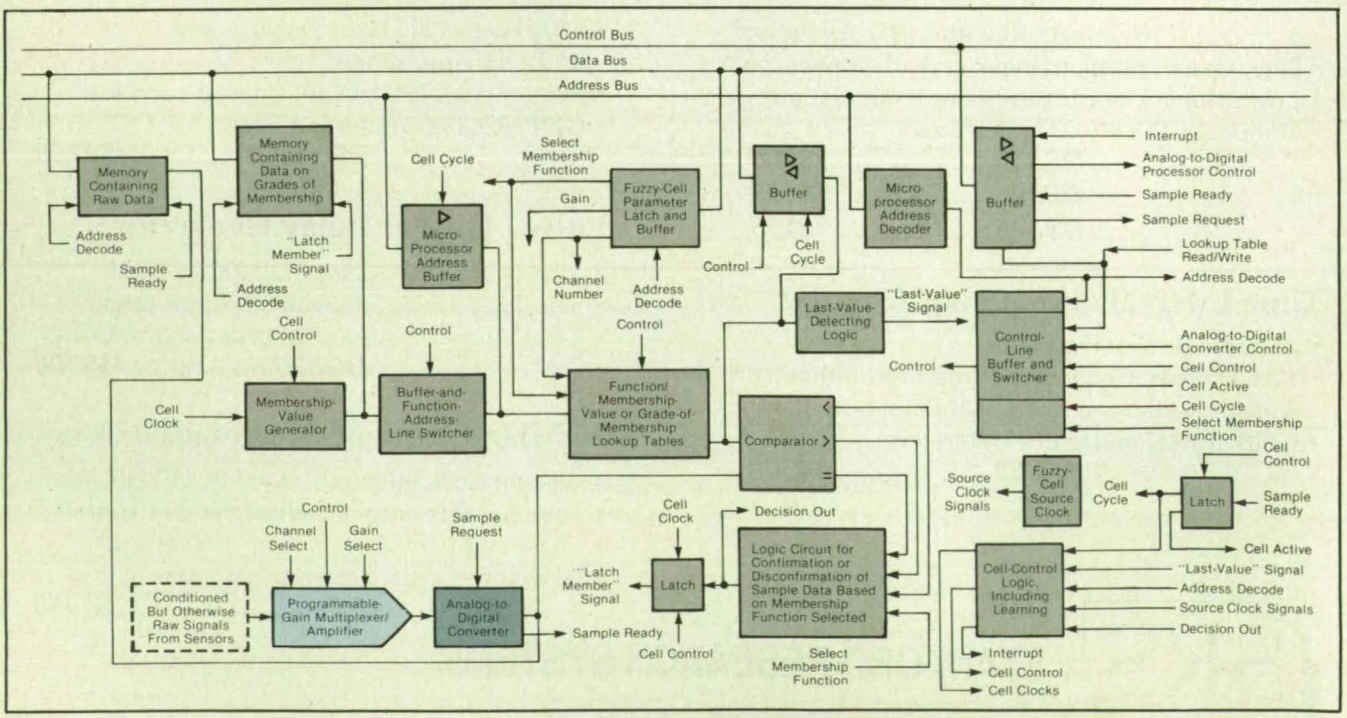
The reconfigurable fuzzy cell (see figure) would provide a flexible multiplex or nonmultiplex configuration for the implementation of typical membership functions or combinations of various functions to form hybrid membership functions based on fuzzy-level-set theory. The function to be used at a given time for converting the digitized sample would be selected, by the central fuzzy controller/processor, from the function/membership-value or grade-of-membership lookup table stored in memory in the reconfigurable fuzzy cell.

The cell would acquire samples of as many as eight raw sensor outputs through a programmable-gain multiplexer/amplifier, digitize these samples, then convert each digitized sample to its grade-of-membership representation, autonomously. The cell would provide the signals that would be needed to incorporate it into an interrupt-driven fuzzy-logic system. The cell also has a data acquisition-only mode, where raw digitized data can be acquired from newly replaced sensors for developing new membership functions. The new membership function would then be programmed into the lookup table. Because the design of the cell would not depend on any particular computer, interface circuit, or programming language, the design could accommodate any of a variety of digital-interface options and programming schemes for reconfiguration.

A typical sequence of operations would begin with the deactivation of the cell when the power was first turned on. Next, the central fuzzy controller/processor would select the sensor channel, the function circuitry, and memory block in the lookup table containing the function data to convert the digitized sample into its grade-of-membership, and the sensor channel scaling factor. The processor would then issue a start of the analog-to-digital (A/D) conversion process. Upon the arrival of the digitized sample, the cell would become active and remain active until inhibited by a command from the central fuzzy controller/processor. While active, the cell would convert the sampled raw sensor signals into both binary and grade-of-membership representations. Afterwards, a "cell-interrupt" signal from the cell would notify the central fuzzy controller/processor that both representations are available for retrieval. The above process is repeated for the next sensor channel, which is made by the central fuzzy controller/processor during the "cell interrupt" routine.

*This work was done by George A. Salazar of* **Johnson Space Center**. *For further information, Circle 31 on the TSP Request Card.*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 20]. Refer to MSC-21613.*




The **Reconfigurable Fuzzy Cell** would provide real-time, high-throughput, interrupt-driven, multiplex conversion of sampled raw signals from sensors into their grade of membership for use in a fuzzy-logic control system.

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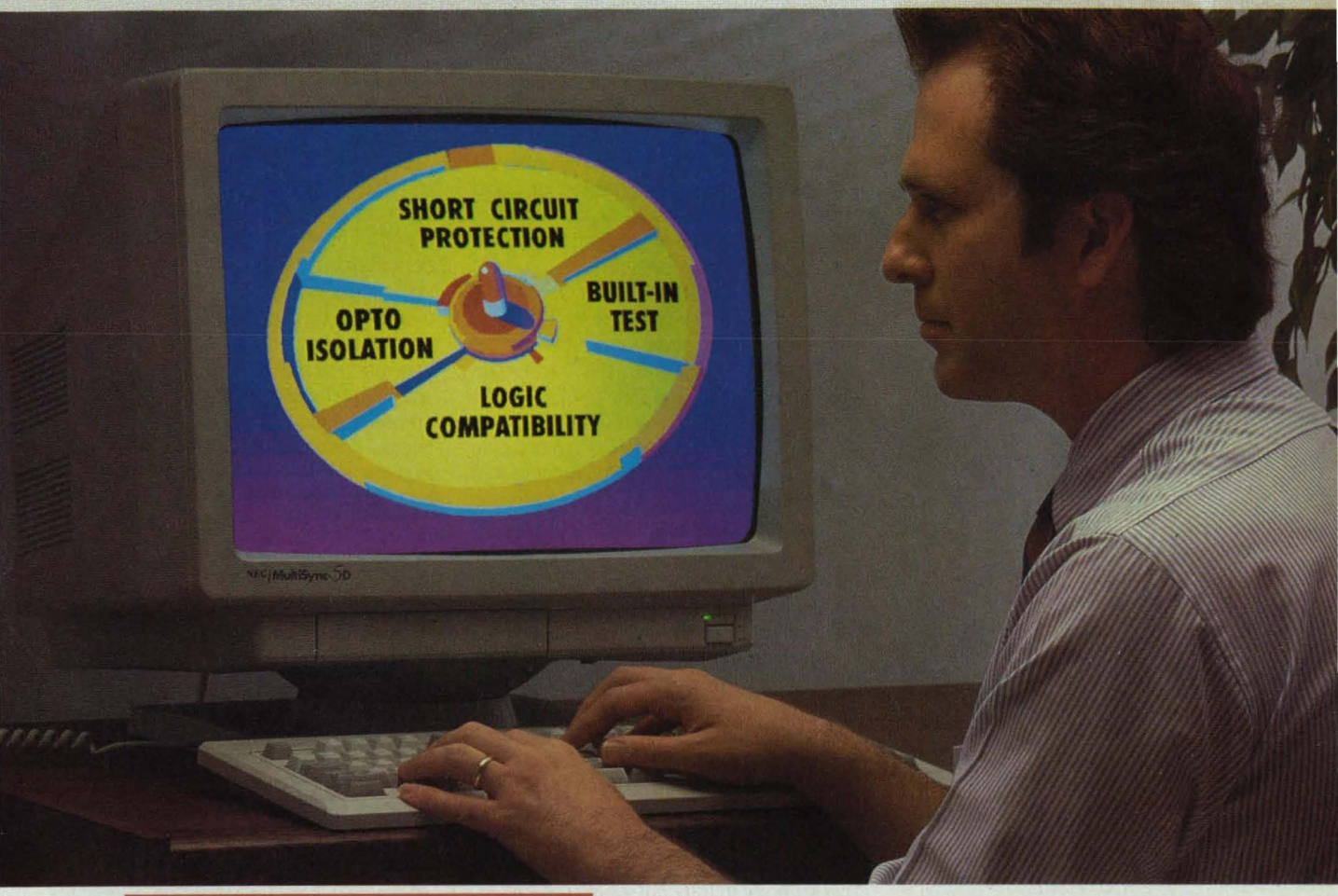


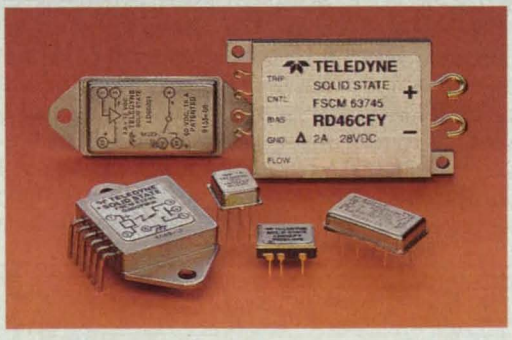


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# Fast Vector-Quantizing Data Compressor

Features would include reliability, light weight, and low power.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A proposed encoding digital electronic data-processing system would compress a 7-Mb/s input stream of data into a 1-Mb/s output stream. This system is intended to reduce the flow of data from an orbiting synthetic-aperture-radar (SAR) system to a rate low enough for transmission to the ground. The basic design concept could also prove advantageous in such terrestrial applications as compression of speech and of video signals.

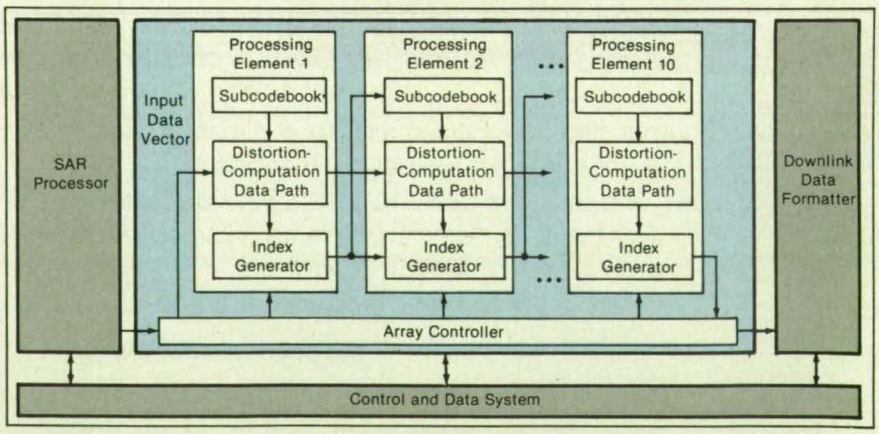
The design of the data compressor would be based on a binary-tree-search vector-quantization algorithm. As in other vector-quantization algorithms, the input data would be divided into many small blocks (the input vectors), which would be compared with code vectors in electronic memory (the "code book"). The output of the compressor (the encoded, compressed data) would be the index number of the code vector that matched the input vector most closely, as indicated by the minimization of a prescribed scalar measure of distortion. Quantization by choice of the closest code vector necessarily entails the loss of some data, but a suitable design can keep the loss small: the design specification for the original SAR application, in which the data represent radar brightnesses of picture elements, calls for an average radiometric error of less than ±0.5 dB.

In full-search vector quantization, an input data vector is compared with every code vector in the code book, but this entails too much complexity. In the binary-tree-search algorithm of the proposed system, the code book would be divided into subcode books arranged in a binary tree structure; the input vector would be compared successively with the code vectors in the selected subcode books, finding the way through the tree incrementally by finding the best match at each level. At the end of passage through all levels of the tree, the binary tree index that represents the best match would be the compressed representation of the input vector.

The particular binary-tree-search vector-quantization algorithm offers a distinct advantage in that it is well suited to implementation in very-large-scale integrated (VLSI) circuitry. Because the operations performed at successive levels rely on the same logic, identical data-processing elements can be organized physically into a cascade (also known variously as "pipeline" and "systolic array"), and all can operate simultaneously, processing different stages of successive input data. The conceptual design would thus be modular, with regular flow of data. An array-controlling processor would exert simple control and would serve as the interface between the input source processor (in this case, the SAR data processor) and the output sink processor (in this case, the downlink data formatter) (see figure).

There would be 11 identical processing elements, one of which would be a spare. In the event that a special control register detected a permanent fault in one of the 10 operating processing elements, it would activate reconfiguration switches to disconnect the faulty processing element and connect the spare. The entire system would contain about 30 integrated-circuit chips, with all processing elements on one of the chips. The system would contain about 40,000 transistors and 77 contact pins. It would consume a maximum power of 4 W while operating at the anticipated maximum data rate (880 kHz). The system would weigh about 1.2 lb (0.54 kg).

*This work was done by Chi-Yung Chang, Wai-Chi Fang, and John C. Curlander of*




The **Data Compressor** would be designed to include features that are particularly suitable for implementation in VLSI. These include modularity, regular flow of data, simple interconnection, localized communication, simple global control, and parallel/pipeline processing.

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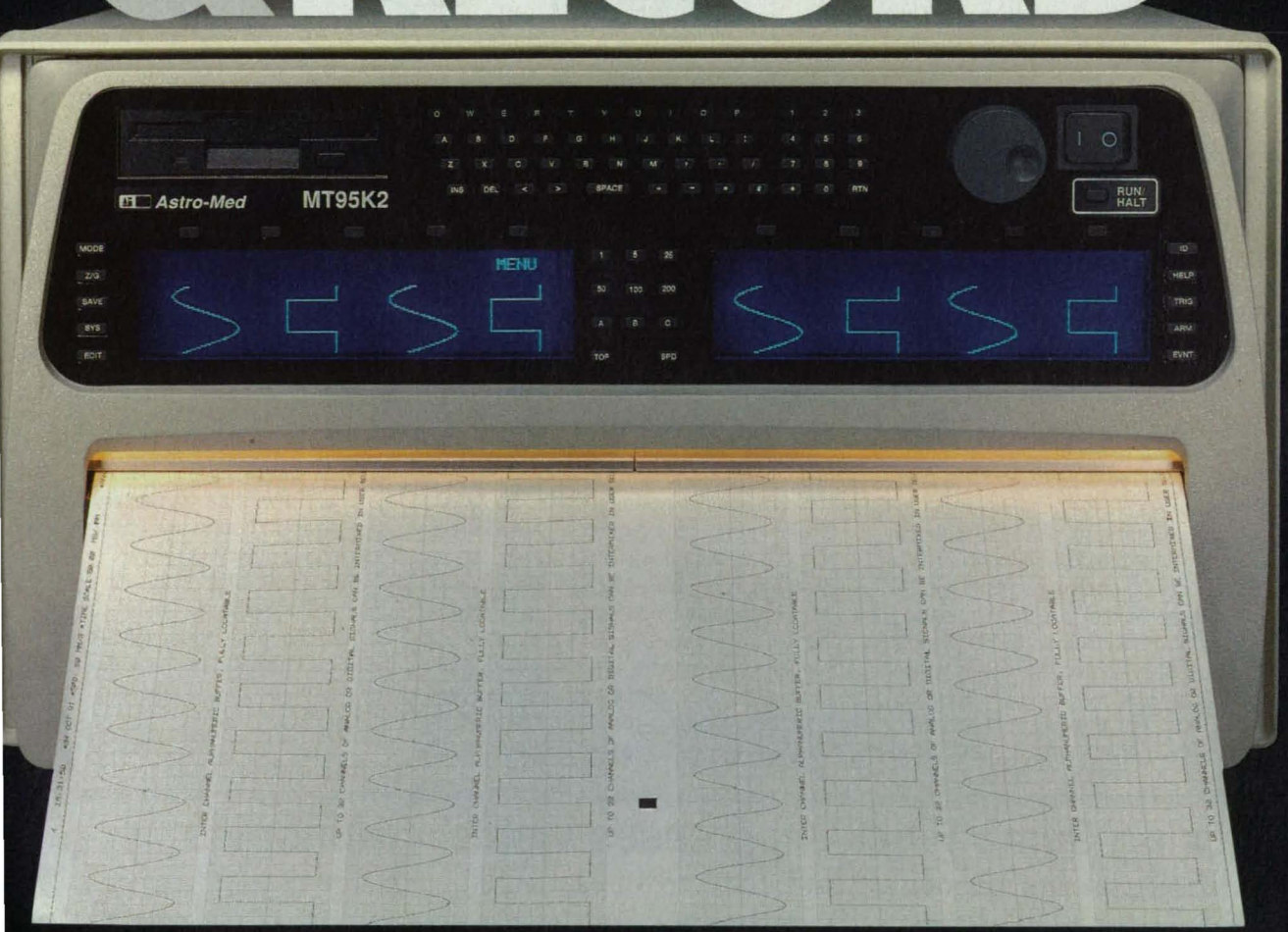


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*Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 40 on the TSP Request Card.*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 20]. Refer to NPO-17941.*

# Publication of Oceanographic Data on CD-ROM

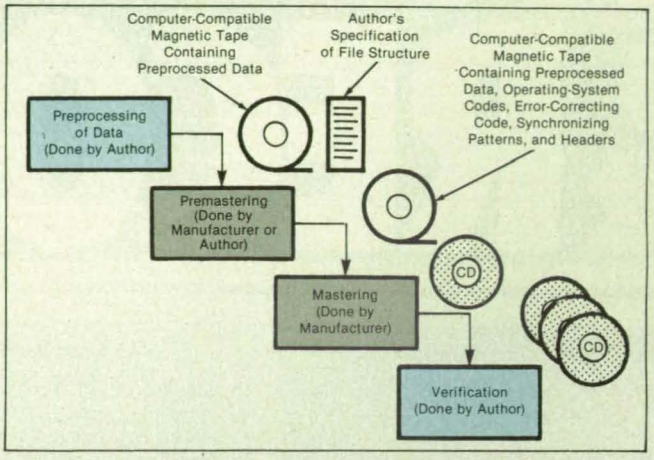
CD-ROM offers advantages over 9-track computer tape.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Oceanographic data gathered by satellite-borne radiometers, radars, and other remote sensors are now (early 1992) being published on optical compact-disk read-only memories (CD-ROMs) like those now used in the audio industry. The increasing size of data collections creates difficulties in access, transfer, and storage on the traditional recording medium, which is 9-track computer-compatible magnetic tape. These difficulties can be alleviated by the high capacity (600 MB), small size (120-mm diameter), and light weight (only 15.5 g) of the standard CD-ROM. Furthermore, the logical format specified by the present standard 9660 of the International Standards Organization (ISO) makes it possible to use CD-ROM's with readers and computers built by different manufacturers.

The publication of data on CD-ROM involves four major steps: preprocessing, premastering, mastering, and verification (see figure). Premastering and mastering are complicated manufacturing processes in which the preprocessed data on 9-track tape are transferred to polycarbonate disks. The techniques of premastering and mastering are well established in the industry; consequently, efforts to develop this method of publication must focus on the problems of preprocessing and verification, which must be performed by the author.

Preprocessing is necessary to organize the data into files that will facilitate access and use. Although the ISO 9660 standard specifies the general arrangement of information on a disk, it does not define the arrangement of the author's data within a file. Using the ISO 9660 format, the author can specify relationships between directories and files. Research has shown that grouping data into categories and hierarchies facilitates searching and sorting. For example, files of data can be partitioned according to type and time and hierarchically in space and time.




**Large Collections of Oceanographic Data** (and presumably other large collections of data) could be published on CD-ROM's in formats that facilitate access and analysis. The large capacity, small size, commercial availability, long-life, and standard format of CD-ROM's offer advantages over computer-compatible magnetic tape.

Verification is not as trivial a matter as it might seem at first glance. Data can be lost in premastering if errors are made in preprocessing; for example, if the name of a file is specified incorrectly or if the number of data exceed the specified size of the file. Prior to mass replication of disks, the author should verify the integrity of a sample completed disk — a labor-intensive task that requires visual inspection of directory and file structures. Particular effort should be made to assure conformance of names and hierarchical levels to those in the specification. The contents of directories of files should be checked for correctness, and retrieval software should be exercised. The author should also review human factors that affect the recognition and use of particular sets of data — e.g., labeling, supporting documentation, "help" files, acronyms as names of directories and files, and software capabilities that enhance usability.

*This work was done by Jeffrey E. Hilland, Elizabeth A. Smith, and Michael D. Martin of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 55 on the TSP Request Card.*
*NPO-18270*

# Tracking Comb Filter Suppresses Welder Harmonics

Spurious signals are reduced almost to the fundamental limit.

*Marshall Space Flight Center, Alabama*

A tracking comb filter removes harmonics of welding-current pulses from the amplified output of a sensor that monitors higher-frequency acoustic emissions during welding. The welding-current harmonics enter the acoustic-emission circuitry through spurious electromagnetic coupling from the 300-A pulses of welding current plus undesired acoustic coupling from the welding arc to the sensor. The comb filter is needed because (1) the harmonics are stronger than the acoustic-emission signal is and therefore interfere with the observation of the acoustic emissions and (2) conventional shielding, band-pass filtering, and differential-amplification techniques have not succeeded in removing the harmonics.

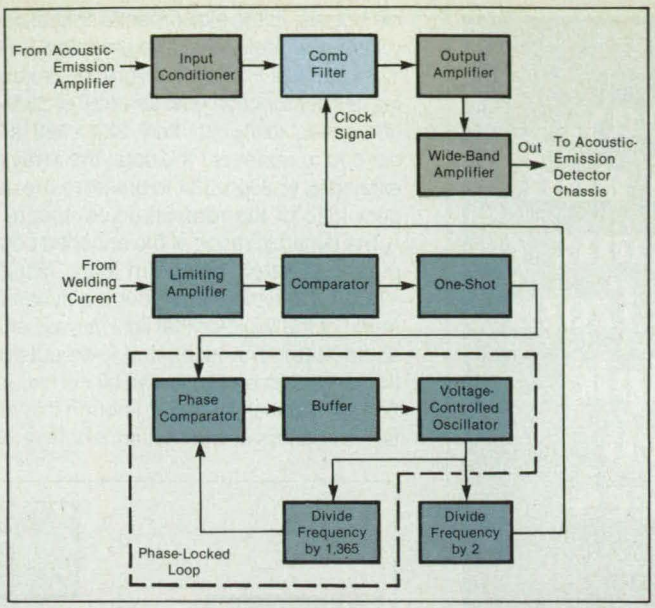
The tracking comb filter is so named because it tracks the fundamental frequency of the welding-current pulses and because a plot of its transfer function (output amplitude/input amplitude vs. frequency) is a comblike sequence of rejection bands at the harmonic frequencies interspersed with passbands. This filter removes the harmonics by rejecting the entire portion of the signal (including the desired portion of the acoustic-emission signal) that lies in the rejection band at each harmonic frequency.

The fundamental frequency (the rate of repetition) of the current pulses is ≈16 kHz, and the durations of the pulses are varied to control the time-averaged welding current. The acoustic emissions that one seeks to monitor are a series of wide-band "pops" in the frequency range of 250 to 1,000 kHz. The welding-current harmonics persist at frequencies as high as 2 MHz. The comb filter removes a portion of the spectrum at each harmonic interval of about 16 kHz, the total amount removed being about half the total spectrum. However, the remaining spectrum contains the basic absolute-amplitude

information needed to characterize the acoustic-emission signal.

The tracking comb filter (see figure) includes a standard comb filter, which contains a charge-coupled-device (CCD) delay line. The tracking capability is imparted by a phase-locked loop. The voltage-controlled oscillator portion of the phase-locked loop, controlled by the phase comparator, runs at a harmonic frequency that nominally equals the fundamental welding-current frequency multiplied by the number of "buckets" in the delay line. Several programmable counter chips divide this frequency by the number of "buckets," and a phase comparator compares the frequency of the resulting signal (nominally, the fundamental frequency) with the actual fundamental-frequency signal. The output of the phase comparator is the voltage that keeps the voltage-controlled oscillator in lock. The delay of the CCD is thus maintained at the pulse-repetition period.

In tests, the tracking comb filter worked quite well. It removed the 16-kHz harmonics from 300 to 1,000 kHz so well that the noise in the output signal approached the fundamental Johnson-noise (thermal-electron noise) limit.




The **Tracking Comb Filter** includes a charge-coupled-device delay line and a phase-locked loop. This filter removes harmonics of the frequency of repetition of welding-current pulses from the acoustic-emission signal.

*This work was done by Ray C. Delcher of Rockwell International Corp. for* **Marshall Space Flight Center**. *For further information, Circle 64 on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-29736.*

# Optical Correlator With Complex Holographic Filter

The correlator can be made more tolerant of errors in patterns to be recognized.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

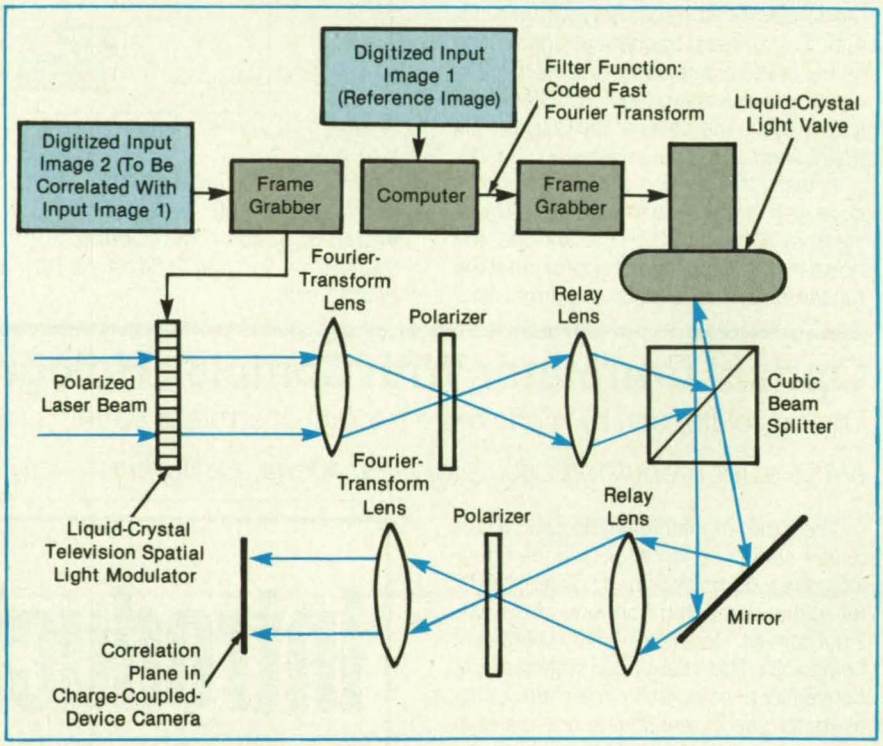
The experimental real-time optical correlator shown schematically in the figure includes a complex-valued holographic filter that is computed from one of the two input scenes. Heretofore, binary phase-only holographic filters have been preferred over conventional holographic matched spatial filters for use in real-time optical correlators because they entail less complexity in the processing and display of image data and because the binarization of filter functions magnifies the higher-spatial-frequency components of images, with consequent increases in the sharpnesses of correlation peaks. Unfortunately, the ability to discriminate between input images that are similar except for noise, differences in contrast, and other relatively minor differences and errors is degraded when binary phase-only filtering is used. Because the experimental filter retains both the amplitude and phase information of the filter function, it works better in the presence of such errors and differences.

The filter function is essentially a coded hologram computed by Burchhardt's method, in which the complex value (representing amplitude and phase) of each pixel of a fast Fourier transform of the image is represented by three real, nonnegative numbers. In generating an optical correlator according to this method, the phasor of each pixel in the Fourier transform is thus represented by the intensities in three adja-

cent pixels. In the experimental optical correlator, the method is implemented for a 128×128 fast Fourier transform by projecting its filter function onto an array of 384×384 pixels (although only 384×128 are needed to represent the data, the array is expanded to 384×384 to preserve the aspect ratio of the reconstructed image).

The dynamic range of the encoded computer-generated hologram can exceed 1,000:1 in a typical case, but the dynamic range of the liquid-crystal light valve is only about 100:1. The highs and lows outside the range can be eliminated by normalization and spatial filtering. Although this entails some loss of information, it can nevertheless confer an advantage, depending on the application. For example, as in the case of binary phase-only filtering, high-pass filtering increases the sharpness of the correlation peak. Low-pass filtering decreases the sharpness of the correlation peak but increases tolerance of errors. It should be possible to develop a real-time optical correlator with an updatable spatial filter that can be optimized for the application at hand.

*This work was done by Tien-Hsin Chao of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 19 on the TSP Request Card.*
*NPO-18464*




This **Real-Time Optical Correlator** is based on the use of a coded hologram that conveys the phasor data of a fast Fourier transform of input image 1.

## Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

### Arraying Techniques in the Deep Space Network

Techniques for combining weak radio signals received at several antennas are compared.

A report discusses the performances of a number of techniques for combining radio signals received at several antennas to increase the signal-to-noise ratio of a specified weak signal that bears digital data via phase modulation. The basic idea is to synthesize the effect of a larger antenna or, equivalently, an array of antennas. Called "arraying," the techniques are used in the Space Network to extend the range of reception of signals from spacecraft as they travel beyond distant planets.

The arraying techniques studied are symbol-stream combining, baseband combining, carrier arraying, and full-spectrum combining. An ancillary technique called sideband aiding (which involves only one antenna) is also mentioned and included in the analysis but not described. Combinations of these techniques (e.g., carrier arraying with sideband aiding and baseband combining or carrier arraying with symbol-stream combining) are also discussed.

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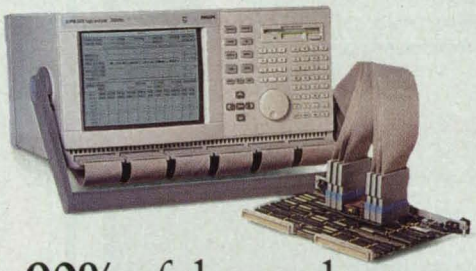

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In symbol-stream combining, the receiver at each antenna acts individually in tracking the carrier and subcarrier and synchronizing the data symbols. The symbols put out by each receiver are then combined with appropriate weights, either in real time or in postprocessing, to form the final detected symbols.

In baseband combining, the receiver at each antenna acts individually in locking on the signal. The baseband signal put out by each receiver consists of data modulation on a subcarrier; these baseband signals are aligned and combined, and the data symbols are obtained by demodulating the combination subcarrier.

In full-spectrum combining, the signals from the separate receivers are combined at the intermediate frequency. The process of combination can be characterized as two-dimensional in the sense that both delays and phases must be adjusted to obtain coherent addition of the signals. The combination intermediate-frequency signal is then processed through one receiver chain that includes carrier-tracking, subcarrier-tracking, and symbol-synchronizing loops.

In carrier arraying, the carrier-tracking loops of several receivers are coupled to enhance the signal-to-noise ratio of the received carrier. In the case of a residual carrier, coupling can be effected via phase-locked loops; in the case of binary phase-shift keying with a suppressed carrier, coupling can be effected via Costas loops. Carrier arraying can be performed at intermediate frequency or at baseband. Because carrier arraying does not combine the data, it must be used in conjunction with baseband combining or symbol-stream combining.

Equations that describe pertinent aspects of the performance of each technique are presented. Numerical examples are provided for each technique and combination of techniques as applied to weak, medium, and strong signals from the Pioneer 10, Voyager II, and Magellan spacecraft. On the basis of this analysis, the report concludes that for the reception of a weak telemetry signal in which the ratio between the subcarrier frequency and the data rate is large, baseband combining with carrier aiding and possibly also with sideband aiding provides the best performance. For stronger signals, full-spectrum combining and baseband combining with carrier aiding are both well suited and perform comparably.

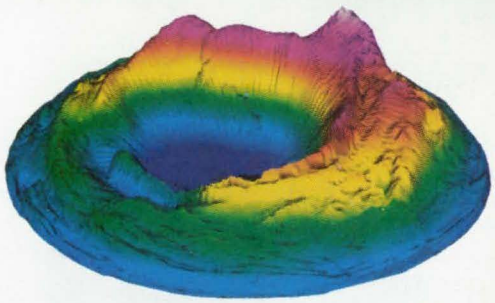
*This work was done by Alexander Mileant and Sami M. Hinedi of Caltech for* **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Overview of Arraying Techniques in the Deep Space Network," Circle 2 on the TSP Request Card.*
*NPO-18455*

# TECHNOLOGY 2002

# UPDATE

The latest news about the nation's premier technology showcase

## America's Best Inventions And Top Researchers Are Coming To Baltimore This December



NASA's Flow Analysis Software Toolkit, the subject of a Dec.1 presentation, offers a powerful tool for visualization of scientific data, as exemplified by this model of the ozone hole over Antarctica.

"Magic bullets" for cancer therapy ...a dexterous robot that tackles jobs too tough for humans...an assembly technique that dramatically improves integrated circuit performance...wireless infrared telephones...an ingestible pill that takes your temperature with extreme accuracy.

These are just a few of the hundreds of practical innovations that will be displayed and discussed at Technology 2002, the third national technology transfer conference and exposition, to be held December 1-3 in the Baltimore, MD convention center. Sponsored by NASA, *NASA Tech Briefs* magazine, and the Technology Utilization Foundation, Technology 2002 will show businesses how to tap into the U.S. government's $70 billion technology bank to solve engineering problems, create new or improved products, and refine their manufacturing/production processes. The three-day show will feature:

- *Over 120 presentations spotlighting inventions with commercial promise in manufacturing, materials, computing, communications, biotechnology, and energy/environment, areas identified by the White House as National Critical Technologies;*
- *Hands-on workshops covering the "ins and outs" of patent licensing, cooperative R&D, and research grants, as well as sessions on university-based and international technologies U.S. companies can tap into to bolster their competitiveness;*
- *60,000 square feet of exhibits showcasing new inventions and products available for license or sale from the federal labs, their contractors, and other high-tech firms and universities;*
- *The third annual Technology Transfer Awards Dinner, offering an unparalleled opportunity to network with government and industry executives in an elegant setting—the Baltimore Hyatt's Grand Ballroom. Norman Augustine, Chairman and CEO of Martin Marietta Corp., will speak at the Dec. 2 dinner, which will feature achievement awards to federal technologists and contractors who have made important strides in translating research advances into products and processes that benefit the economy and daily life.*

Conference speakers will include leading technology developers and tech transfer experts from NASA, NOAA, the EPA, and the departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, Interior, Transportation, and Veterans Affairs. Maryland Senator Barbara Mikulski will deliver the opening address on Dec. 1, while Rockwell International Executive Vice President and Chief Operating Officer Sam Iacobellis will serve as keynote speaker the following day. The General Conference Chairman is James R. Thompson, Executive Vice President of Orbital Sciences Corp., formerly NASA Deputy Administrator.


From Jet Propulsion Lab: the "Data Egg," a handheld device that allows computer text entry with only one hand.

Over 6000 engineers and executives are expected to attend Technology 2002 and the two other complementary events that comprise National Technology Transfer Week (see article next page). *To register, fill out and mail or fax the form on page "H."*

**TOP-LEVEL SPEAKERS:**

**Norman R. Augustine**
*Chairman and CEO, Martin Marietta Corp.*

**Barbara A. Mikulski**
*Senator, State of Maryland*

**Sam F. Iacobellis**
*Executive Vice-President & Chief Operating Officer, Rockwell International*

**James R. Thompson**
*Executive Vice-President Orbital Sciences Corp.*

## National Technology Transfer Week Nov. 30 - Dec. 5 1992

**Working To Keep America Strong**

There has never before been anything like it! Three high-powered events coming together to help U.S. industry utilize cutting-edge technology to gain a competitive edge in the global marketplace. In addition to Technology 2002, Technology Transfer Week will include:

### ▶ The President's National Technology Initiative (NTI)

**DATE** December 1, 1992
**PLACE** Baltimore Convention Center

To be held concurrently with Technology 2002's Tuesday sessions, the NTI will focus on opportunities for partnerships between the government, academia, and U.S. companies to turn new technologies into marketable goods and services. *NTI plenary sessions and workshops are open to Technology 2002 symposia registrants at no additional cost.*

### ▶ MIT Entrepreneurial Tech Transfer Conference

**DATE** December 3-5,1992
**PLACE** Baltimore Hyatt Hotel

This world-class conference, sponsored by the Massachusetts Institute of Technology Enterprise Forum, will feature more than 25 "how to" sessions and interactive tutorials designed to provide the tools needed to commercialize new technologies and capitalize on partnership opportunities such as those featured at Technology 2002 and the NTI.

***For more information, call (617) 862-0397***

# T2002 Symposia To Spotlight "National Critical Technologies"

Technology 2002 symposia will explore a wealth of inventions available for license or joint development in areas selected by the White House Office of Science and Technology Policy as critical to the nation's economic future: advanced manufacturing, materials, high-performance computing, communications, biotechnology/life sciences, and energy/environment. During concurrent sessions, more than 120 emerging technologies will be described by federal lab researchers and their contractors, with the focus on possible commercial uses. Some highlights:

▶ NASA will present over 50 technologies for transfer, including two that promise safer skies: a compact, energy-efficient aircraft deicer that employs electrical pulses to pulverize ice before it can cause engine damage, and an artificial intelligence (AI) system that checks the health of aging airplanes;

▶ The Air Force sponsored development of a laser system that rapidly and accurately measures complex, contoured production parts—a major boon to manufacturing; also from the Air Force: a novel technique for reassembling bare integrated circuits that dramatically improves IC performance while shrinking component size and weight;

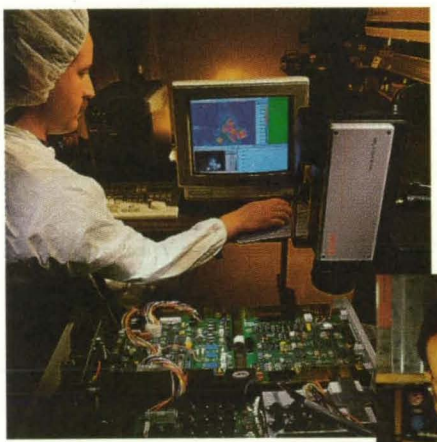
▶ Johns Hopkins University will show a computerized system for breast cancer detection that enables physicians to spot tumors at an earlier stage and accelerate treatment, greatly increasing the patient's chances of survival;

▶ The Department of Energy will discuss environmental breakthroughs such as a process for removing toxic metals from soils that can be applied to a variety of waste forms and a "fuzzy logic" controller that offers a clear-cut solution to water waste problems;

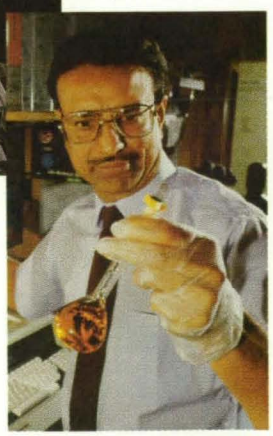
▶ Navy researchers will detail an array of computer advances, including an application protocol that permits the transfer of files between dissimilar CAD systems and a PC-based video system that incorporates eye tracking and voice command control technology for "hands-free" computing;

▶ Boeing will unveil an industry first: a robotic variable-polarity plasma arc welder developed for space station Freedom that produces highly-reliable, porosity-free aluminum welds; and Jet Propulsion Lab will demonstrate a dexterous robot built to tackle tasks too dangerous or impractical for humans, such as handling nuclear waste materials.

Adding an exciting new dimension to this year's program are Wednesday and Thursday afternoon sessions on university-based and international technologies U.S. firms can acquire through licensing or partnering arrangements. University speakers will include John Preston, Director of MIT's Technology Licensing Program, while the international panels will feature experts from such nations as Canada, England, Russia, Taiwan, and France, the latter represented by Jean-Pierre Fouquet, President of Novespace, France's main technology transfer organization.



AGEMA Infrared Systems will demonstrate heat-sensing camera systems useful in manufacturing quality control, medical diagnostics, and a variety of other applications.



Brookhaven researchers will report on a new technique for extracting toxic metals from contaminated soil.

**Turn to pages D-G for a complete list of sessions and symposia presentations.**

# Technology 2002 Exhibits: Your One-Stop Source For Innovative Ideas

The National Institute of Standards & Technology (NIST) will describe a novel measurement technique that has become the dominant force in evaluating and calibrating the performance of complex antennas.

"If the future had a department store, this would be it." That's how CNN described the exhibits hall at last December's Technology 2001 conference in San Jose. This year in Baltimore the exhibits area has been expanded by nearly 25 percent (for a whopping total of 60,000 square feet) and will feature an even broader array of cutting-edge technologies and resources that industry can tap into to create tomorrow's products and processes. Over 50 federal laboratories—representing a dozen major government agencies—and 200 companies and universities will be demonstrating their latest inventions and products available for license or sale.

This year, for the first time, admission to the exhibits hall is free of charge. "We fully realize these are challenging times for many businesses," explained Show Director Wendy Janiel, "and we want to make sure as many U.S. companies and entrepreneurs as possible have the opportunity to take advantage of this incredible wealth of technology."

The Technology 2002 exhibits hall is nearly sold out, but a few choice spots still remain as of press time. Organizations interested in exhibiting should contact Wendy Janiel immediately at (800) 944-NASA. Following is a partial list of current exhibitors:

AECL Technologies
Advanced Technology & Research Corp.
Aerospatiale
AGEMA Infrared Systems
Air Force Materiel Command
Allied-Signal Aerospace Co.
Ambassador Marketing
American Ceramic Society
American Welding Society
Amerinex Artificial Intelligence
Ames Laboratory
Ames Research Center
Army Corp. Of Engineers
Army Electronics Technology And Devices Lab
Army Research Institute Of Environmental Medicine
Army Research Laboratory
Amtec Engineering Inc.
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Association Of American Railroads
ASTM
Astro-Med Inc.
Aviation Week Group
Bergen Cable Technologies Inc.
BF Goodrich Aerospace
Biophysics Research Foundation
Biotronics Technologies
Birch, Stewart, Kolasch, & Birch
Boeing Company
Brookhaven National Laboratory
Caltech Supercomputer
Cannon Communications
Center For Aerospace Information
CI Systems Inc.
C. Itoh Technology Inc.
Columbia University
Concurrent Technologies Corp.
Control Systems Analysis
Cornell Theory Center
Cornell University
Corning Inc.
COSMIC/University Of Georgia
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CTA Inc.
Cybernet Systems Inc.
Daedalus Enterprises Inc.
Dartmouth University
Datatape Inc.
Defense Programs Technology Transfer
Diamonex Inc.
Digiray Corp.
Digital Equipment Corporation
Dual Inc.
Edison Sensor Technology Center
Evans & Sutherland
Federal Highway Administration
Federal Laboratory Consortium
Fermi National Accelerator Lab
Ferrofluidics Corp.
FLIR Systems Inc.
Fluid Dynamics International
General Pneumatics Corp.
Goddard Space Flight Center
Hemco Corp.
High Technology Systems Inc.
Idaho National Engineering Lab
Iitri Assurance Technology Center
Impra Inc.
Information Handling Services
Inframetrics Inc.
Infrared Information Analysis Center/ERIM
Innovation 128 Inc.
INPEX/INTROMARK
Institute Of Environmental Sciences
Integrated Engineering Software
Integrated Sensors Inc.
International Computers & Telecommunications
International Environmental Institute
Ithaco Inc.
Ivy League Universities Technology Transfer
Jet Propulsion Laboratory
Johnson Space Center
Kennedy Space Center
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Los Alamos National Lab
Machida Inc.
MacNeal Schwendler Corp.
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Martin Marietta Energy Systems
Maryland Department Of Economic & Employment Development
Massachusetts Institute of Technology
McClellan Air Force Base
MCNC Center For Microelectronics
MERP Enhanced Composites
Mid-Atlantic Technology Applications Center
Millitech Corporation
Modular Instruments Inc.
Moltech Corporation
Morgantown Energy Technology Center
NASA
NASA Centers For The Commercial Development Of Space
NASA Regional Technology Transfer Centers
NASA Scientific And Technical Information Program
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North Carolina State University
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NYMA Inc.
Oak Ridge National Laboratory
Oklahoma Center For Design And Manufacturing
Oneida Research Services
Pacific Northwest Laboratory
Pennsylvania State University
Photonic Systems Inc.
Pittsburgh Energy Technology Center
Precision Filters Inc.
Princeton Plasma Physics Lab
Proto Manufacturing
Ramtek Corporation
Research Triangle Institute
RGB Spectrum
RG Hansen
Ribbon Technology
Sandia National Labs
Satellite Data Systems
Scientific Research Associates
Small Parts Inc.
Sonic Perceptions Inc.
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Stephens Analytical Inc.
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Technical Insights Inc.
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Technology Transfer Society
Technology Utilization Foundation
Techron, Div. Of Crown International
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Thiokol Corporation
Tiodize Company
Turbomixer Corp.
United Technologies/USBI Corp.
University Of Dayton Research Institute
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U.S. Alcohol and Drug Testing
U.S. Army Aeromedical Research Lab
U.S. Army Belvoir Research, Development, & Engineering Center
U.S. Bureau Of Mines
U.S. Department Of Agriculture
U.S. Department Of Energy/Conservation & Renewable Energy
U.S. Department Of Energy/Triodyne
U.S. Environmental Protection Agency
U.S. Naval Academy
Vector Aeromotive Corp.
Vermont Research Corp.
Walter, Reed AMC
Westinghouse Hanford Co.
Wolfram Research Inc.

## Monday, November 30

6:00 - 8:00 pm

**Technology Transfer Week Opening Ceremonies & Reception**
*Speaker: Governor William Donald Schaefer, State of Maryland (invited)*

## Tuesday, December 1

8:30 - 10:00 am

**Opening: Federal Technology Overview**

Keynote Address:
*Senator Barbara Mikulski, State of Maryland*

National Technology Initiative—Opening Remarks:
*Speakers at previous NTI opening sessions have included the following dignitaries:*
*Barbara Hackman Franklin, Secretary, U.S. Department of Commerce*
*Daniel S. Goldin, Administrator, NASA*
*John W. Lyons, Director, National Institute of Standards and Technology*
*William K. Reilly, Administrator, U.S. Environmental Protection Agency*
*James D. Watkins, Secretary, U.S. Department of Energy*

10:00 - 11:00 am

**Plenary Theme Panels**
*(Panelists to be announced)*
Cooperative Research And Development; Investment And Financing; Manufacturing Excellence.

11:00 - 11:45 am

**Government-Industry Dialogue**
Answers to your questions about the technology transfer process, partnering opportunities, and federal technology resources and contacts.

1:00 - 3:00 pm

**National Critical Technologies Concurrent Sessions**
*Each presentation will last 30 minutes, including questions and answers. Registrants may choose to attend whole sessions (four presentations) or individual presentations from a number of different sessions. Meeting rooms are situated in close proximity for easy and quick movement during sessions. Room assignments will be listed in the final program distributed at the show.*

▶ Session A101

### ADVANCED MATERIALS PART 1

**INEL Spray Forming Research**
*Kevin M. McHugh and James F. Kay, Idaho National Engineering Lab*

**Film Fabrication Technologies**
*Robert D. McConnell, National Renewable Energy Lab*

**The Effect of Hydrogen on the Optical and Scratch-Resistant Properties of Diamondlike Carbon Films**
*Michael T. Kussmaul, Sverdrup Technology Inc.; Bruce A. Banks, and Michael T. Mirtich, Lewis Research Center*

**The Effect of Extrusion on PS-212 Self-Lubricating Materials**
*W.J. Waters, Sverdrup Technologies Inc.; H.E. Sliney, Lewis Research Center; and R.F. Soltis, Cortez III*

▶ A102

### BIOTECHNOLOGY AND LIFE SCIENCES PART 1

**Measuring the Metastatic Potential of Cancer Cells**
*Dr. Dennis R. Morrison, Johnson Space Center; Dr. Howard Gratzner, DNA Sciences Inc.; and Dr. M.Z. Atassi, Baylor College of Medicine*

**Immunoconjugates: Magic Bullets for Cancer Therapy?**
*Daniel R. Passeri and Jack Spiegel, National Institutes of Health*

**Automated System for Early Breast Cancer Detection**
*Isaac N. Bankman, Johns Hopkins Univ. Applied Physics Lab*

**Design of Mechanically Compatible Fasteners for Human Mandible Reconstruction**
*Jack C. Roberts, John A. Ecker, and Paul J. Biermann, Johns Hopkins Univ. Applied Physics Lab*

▶ A103

### ENERGY AND ENVIRONMENT PART 1

**Cone Penetrometer Measures Spectral Characteristics of Soils In Situ**
*Philip G. Malone and Stafford S. Cooper, U.S. Army Engineer Waterways Experiment Station*

**Soil Reclamation and Recovery of Radionuclides and Toxic Metals**
*Dr. A.J. Francis, Brookhaven National Lab*

**Recovery of Oil and Solids from Oily Sludges**
*Leonard A. Duval, RECOTECH Corp.*

**Low-Cost Dewatering Waste Slurries**
*J.B. Peterson, R.H. Church, and B.J. Scheiner, Tuscaloosa Research Center*

▶ A104

### INFORMATION AND COMMUNICATIONS PART 1: HIGH-PERFORMANCE COMPUTING AND NETWORKING

**High-Performance Networks and Supercomputers for Real-Time Flight Simulation**
*Jeff I. Cleveland, Langley Research Center*

**The SPLASH II Attached Processor System**
*Duncan A. Buell, Supercomputing Research Center*

**Object-Oriented Tools for Distributed Computing**
*Richard M. Adler, Symbiotics Inc.*

**The Database Query Support Processor**
*Patrick McCabe, Rome Laboratory*

▶ A105

### MANUFACTURING TECHNOLOGY PART 1

**"On Machine Tool" 3D Laser Measurement System**
*William L. Shade, Jr., Chesapeake Laser Systems*

**Application of an On-Machine Gauge for Diameter Measurement**
*Kevin Harding, Industrial Technology Institute*

**On-Machine Capacitance Dimensional and Surface Profile Measurement System**
*Ralph Resnick, Extrude Hone Corp.*

**Ultrasonic Polishing**
*Randy Gilmore, Extrude Hone Corp.*

▶ A106

### MICROELECTRONICS/OPTOELECTRONICS PART 1

**Two- and Three-Dimensional High-Performance, Patterned Overlay Multi-Chip Module Technology**
*Capt. James C. Lyke, Phillips Laboratory*

**Improved Performance and Safety for High-Energy Batteries**
*Terrill Atwater, U.S. Army Electronics Technology and Devices Lab*

**Thin Rechargeable Batteries for SRAM PC Card Memory Protection**
*Dennis N. Crouse, EIC Labs*

**Passive Stacking for Improved Vibration Isolation**
*David A. Noever, Marshall Space Flight Center Space Science Lab*

1:30 - 3:00 pm

**National Technology Initiative Concurrent Workshop Series #1**
*(panelists to be announced)*

**Technology 2002** Tuesday symposia registrants are invited to attend these hands-on workshops covering partnership opportunities in **Transportation, Aerospace, and Manufacturing**.

3:30 - 5:30 pm

**National Critical Technologies Concurrent Sessions**

▶ Session B201

### ADVANCED MATERIALS PART 2

**A Novel Method for Detection and Characterization of Superconductors**
*B.F. Kim, Johns Hopkins Univ. Applied Physics Lab*

**Production of Ultrafine, High-Purity Ceramic Powders**
*Jesse L. Hoyer, U.S. Bureau of Mines*

**Mullite Whiskers and Mullite-Whisker Felt**
*Dr. Inna Talmy and Debbie Haught, Naval Surface Warfare Center*

**Graphite/Epoxy Composite Laminates with Interlaminar Damping Layers**
*J. Michael Pereira, Lewis Research Center*

▶ B202

## ARTIFICIAL INTELLIGENCE PART 1

**Expert System for UNIX System Reliability and Availability Enhancement**
*Catherine Q. Xu, Aeronautical Radio Inc.*

**The Generic Spacecraft Analyst Assistant: A Tool for Developing Graphical Expert Systems**
*Peter M. Hughes, Goddard Space Flight Center*

**TARGET: Rapid Capture of Process Knowledge**
*R.T. Savely, C.J. Ortiz, and B.B. Ly, Software Technology Branch, Johnson Space Center*

**Tree Classification Software**
*Wray L. Buntine, Research Institute for Advanced Computer Science*

▶ B203

## BIOTECHNOLOGY AND LIFE SCIENCES PART 2

**Automatic Detection of Epileptic Seizures**
*Dale E. Olsen, Johns Hopkins Univ. Applied Physics Lab*

**A Fiber Optic Probe for Detection of Cataracts**
*Dr. Rafat R. Ansari, Lewis Research Center; and Dr. Harbans S. Dhadwal, SUNY at Stony Brook*

**Heart Rate Spectral Analysis System**
*Hasan Rahman, General Electric Government Services*

**CALMS: Contextual ALarm Management System**
*Karin C. Loftin, KRUG Life Sciences Inc.*

▶ B204

## ENERGY AND ENVIRONMENT PART 2

**Solid-State Isotopic Power Source for Computer Memory Chips**
*Paul Brown, American Nuclear Society*

**Photovoltaic Power Without Batteries for Continuous Cathodic Protection**
*W.W. Muehl, Sr., Navy Coastal Systems Station*

**High-Speed Solid-State Circuit Breaker**
*Thomas F. Podlesak, U.S. Army Electronics Technology and Devices Lab*

**Variable-Speed Generators with Flux Weakening**
*A.A. Fardoun, E.F. Fuchs, and P.W. Carlin, University of Colorado at Boulder*

▶ B205

## INFORMATION AND COMMUNICATIONS PART 2: COMPUTER SIMULATION AND MODELING

**Industrial Applications of Computational Fluid Dynamics**
*Dr. R.R. Chamberlain, Adaptive Research Corp.*

**Scientific Visualization Using the Flow Analysis Software Toolkit**
*Gordon V. Bancroft, Sterling Software Inc.*

**Integration of Design, Thermal, Structural, and Optical Analysis, Including Animation of Thermal Mapping**
*Ruth M. Amundsen, Langley Research Center*

**Data Systems Dynamic Simulator**
*Christopher Rouff, Goddard Space Flight Center*

▶ B206

## MANUFACTURING TECHNOLOGY PART 2

**A Novel Optical/Digital Processing System for Pattern Recognition**
*Bradley G. Boone and Oodaye B. Shukla, Johns Hopkins Univ. Applied Physics Lab*

**Vision-Aided Monitoring and Control of Thermal Spray, Spray Forming, and Welding Processes**
*John E. Agapakis, Automatix Inc.; and Jon Bolstad, Control Vision Inc.*

**Robotic Variable Polarity Plasma Arc Welding**
*Warls S. Jaffery, Boeing Defense and Space Group*

**Firmware Development Improves System Efficiency**
*E. James Chern, Goddard Space Flight Center; and David W. Butler, Paramax Systems Corp.*

3:30 - 5:00 pm

**NTI Concurrent Workshop Series #2**
*(panelists to be announced)*
**Partnerships for Technology Transfer; Protecting Intellectual Property Rights and Technical Data; Financing of Partnerships for Technology Commercialization.**

# *Wednesday, December 2*

9:00 - 9:45 am

**Keynote Address: Meeting the Challenge -- Aerospace Technology Transfer in the Post-Cold-War World**
*Sam Iacobellis, Executive Vice President and Chief Operating Officer, Rockwell International Corporation*

10:00 am - 12:00 pm

**National Critical Technologies Concurrent Sessions**

▶ Session C301

## ADVANCED MATERIALS PART 3

**Electro-Expulsive Separation System**
*Leonard A. Haslim, Ames Research Center*

**Improved Rubber Compound for Tracked Vehicles**
*Dawn Crawford, US Army Fort Belvoir Research, Development, and Engineering Center*

**Dynamic Hardness Tester and Cure Meter**
*Dr. Walter M. Madigosky, Naval Surface Warfare Center*

**Instrumentation Measures Gas Permeability of Polymeric Membranes**
*Dr. Billy T. Upchurch, Langley Research Center*

▶ C302

## ARTIFICIAL INTELLIGENCE PART 2

**A Software Package for Neural Network Applications**
*Robert H. Baran, Naval Surface Warfare Center*

**Control of Complex Dynamic Systems by Neural Networks**
*James C. Spall, Johns Hopkins Univ. Applied Physics Lab*

**Adaptive Process Control with Fuzzy Logic and Genetic Algorithms**
*C.L. Karr, and D.A. Stanley, U.S. Bureau of Mines*

**A Genetic Algorithm Tool for Complex Scheduling Problems**
*Lui Wang, Johnson Space Center*

▶ C303

## ENVIRONMENTAL TECHNOLOGY PART 3

**Development of a LIDAR Mapping Instrument**
*Fran L. Stetina, Goddard Space Flight Center*

**Commercial Applications of a Multispectral Sensor System**
*R. Birk, Lockheed Engineering & Sciences Co.*

**Interactive Forecasting with the National Weather Service River Forecast System**
*George F. Smith, Donna I. Page, and Thomas E. Adams, Hydrologic Research Lab*

**Application of Space Life Support Technology to Terrestrial Environmental Problems**
*Steven H. Schwartzkopf and Bill Walsh, Lockheed Missiles and Space Co.*

▶ C304

## INFORMATION AND COMMUNICATIONS PART 3: COMPUTER GRAPHICS AND DISPLAY TECHNOLOGIES

**Transportable Applications Environment (TAE) Plus**
*Martha R. Szczur, Goddard Space Flight Center*

**Advanced Display Object Selection Methods**
*Glenn Osga, Naval Command Control & Ocean Surveillance Center*

**Universal Index Management System**
*Nick Roussoppulos, Advanced Communications Technology*

**A Natural Language Interface for a Geographic Information System**
*Bruce Davis, Stennis Space Center*

▶ C305

## DATA MANAGEMENT, STORAGE, AND PROCESSING PART 1

**An Application Protocol for CAD to CAD Transfer of Electronic Information**
*Charles C. Azu, Jr., Naval Command Control & Ocean Surveillance Center*

**Methods for Programming Intelligent Searches of Technical Documents**
*David L. Gross, Analex Space Systems*

**An Integrated Information Retrieval and Document Management System**
*L. Stephen Coles, Jet Propulsion Lab*

**Multispectral Lossy Data Compression Using Vector Quantization**
*S. Jaggi, Lockheed Engineering and Science Co.*

▶ C306

## MANUFACTURING TECHNOLOGY PART 3

**Development of a Dexterous, Redundant Manipulator for Space and Ground Robotics Applications**
*James B. Burke, Odetics Inc.*

**An Eight-Degree-of-Freedom Macro-Micro Robot for Precise Force Manipulations**
*Dr. Neville Marzwell, Jet Propulsion Laboratory*

**Fault-Tolerant Intelligent Robotic Control System**
*Dr. Neville Marzwell, Jet Propulsion Laboratory*

**ROBOSIM: An Intelligent Simulator for Robotic Systems**
*Kenneth R. Fernandez, Marshall Space Flight Center; and George E. Cook, Vanderbilt Univ.*

1:00 - 3:00 pm

**National Critical Technologies Concurrent Sessions**

▶ Session D401

## BIOTECHNOLOGY AND LIFE SCIENCES PART 3

**Three-Channel Biomedical Telemetry System**
*Jeffery C. Lesho and Harry Eaton, Johns Hopkins Univ. Applied Physics Lab*

**Implantable Stimulator System Restores Motor Function**
*Dr. P. Hunter Peckham, Department of Veterans Affairs Medical Center*

**Automated System for Analyzing the Activity of Individual Brain Neurons**
*Isaac N. Bankman, Johns Hopkins Univ. Applied Physics Lab*

**Improved Inhalation Technology for Setting Safe Levels of Exposure to Workplace Chemicals**
*Dr. Bruce O. Stuart, Brookhaven National Lab*

▶ D402

## ENERGY AND ENVIRONMENT PART 4

**Active Hydrazine Vapor Sampler**
*Rebecca Young, NASA Toxic Vapor Detection Lab*

**COP Improvement of Refrigerator/ Freezers, Air Conditioners, and Heat Pumps**
*Douglas G. Westra, Marshall Space Flight Center*

**Novel Hot Water Recirculating Technology Conserves Energy/Water**
*Thomas J. Ingalz, Water Control Products Inc.*

**Variable-Volume Flushing Device for Toilet Water Conservation**
*Louis J. Jasper Jr., Harry Diamond Laboratories*

▶ D403

## INFORMATION AND COMMUNICATIONS PART 4: COMPUTER SOFTWARE

**Automated Real-Time Software Development**
*Denise R. Jones, Langley Research Center; and John J. Turkovich, Charles Stark Draper Lab*

**Constraint Checking During Error Recovery**
*Robyn R. Lutz, Jet Propulsion Lab*

**Spin-Off Technology: Engineering and Scientific Computer Codes**
*Bahman Zohuri and Robert Weinheimer, Galaxy Applied Engineering*

**Failure Environment Analysis Tool Applications**
*Ginger Pack, Johnson Space Center; and David Wadsworth, Lockheed Engineering and Sciences*

▶ D404

## INFORMATION AND COMMUNICATIONS PART 5: COMPUTER SIMULATION, VIDEO, AND IMAGING TECHNOLOGY

**Development of Interactive Multimedia Applications**
*Albert Leigh, McDonnell Douglas Space Systems Co.; and Lui Wang, Johnson Space Center*

**Visual Communication in Multimedia Cyberspaces**
*Dr. Joseph Psotka, U.S. Army Research Institute*

**Micro-Video Display with Interactive Ocular Tracking and Voice Control**
*James E. Miller, Naval Undersea Warfare Center*

**Video Conferencing Made Easy**
*D.G. Larsen and P.R. Schwieder, EG&G Idaho*

▶ D405

## MANUFACTURING TECHNOLOGY PART 4

**An Expert System for Superplastic Forming in Concurrent Engineering Environments**
*Deepak Kohli, West Virginia University; Paul Gill and Suren Dwivedi, Marshall Space Flight Center*

**Automated Fiber Placement Composite Manufacturing**
*John H. Vickers, Marshall Space Flight Center*

**Expert System for Signal Validation and Equipment Surveillance**
*Kenny C. Gross and Ralph M. Singer, Argonne National Lab*

**Application of Space Time Neural Networks to Detect Tether Skiprope Phenomena**
*James A. Villarreal, Johnson Space Center*

▶ D406

## MICROELECTRONICS/OPTOELECTRONICS PART 2

**Wireless Infrared Communications for Space and Terrestrial Applications**
*James W. Crimmons, Wilton Industries Inc.*

**Flexible High Speed CODEC**
*J.V. Wernlund and G.P. Segallis, Harris GCSD*

**Ultra-Stable Low-Phase-Noise Dielectric Resonator Stabilized Oscillator**
*Muhammad Mizan, U.S. Army Electronics Technology and Devices Lab*

**Excimer Laser Processing of Backside-Illuminated CCDs**
*Stephen D. Russell, Naval Command Control & Ocean Surveillance Center*

3:30 - 5:30 pm

**Track #1: University Tech Transfer Opportunities**
*(panelists to be announced)*

**Track #2: International Technology Forum: Foreign Inventions for U.S. Benefit**
*(panelists to be announced)*

7:00 - 10:00 p.m.

**Third Annual Technology Transfer Awards Dinner —Hyatt Regency Hotel**
*Keynote Speaker: Norman Augustine, Chairman and CEO, Martin Marietta Corp.*

# *Thursday, December 3*

8:30 - 9:45 am

**Concurrent Workshops: How To Do Business With The Government**
*(Panelists to be announced)*
*Primers on patent licensing, cooperative research, and SBIR opportunities with major government agencies.*

10:00 am - 12:00 pm

**National Critical Technologies Concurrent Sessions**

▶ Session E501

## ADVANCED MATERIALS PART 4

**Applications of Phase Change Polymers in Fibrous Substrates**
*Tyrone L. Vigo and Joseph S. Bruno, U.S. Department of Agriculture*

**Rust Transformers/Rust-Compatible Primers**
*Dario A. Emeric, U.S. Army Belvoir Research, Development, and Engineering Center*

**Method for Predicting Properties of and Tailoring Salt Solutions for Industrial Processes**
*Dr. Moonis R. Ally, Oak Ridge National Lab*

**An X-Ray Scatter Approach for Nondestructive Analysis of Low Atomic Numbered Elements**
*H. Richard Ross, Sverdrup Technology Inc.*

▶ E502

## ARTIFICIAL INTELLIGENCE PART 3

**An Artificial Intelligence-Based Structural Health Monitoring System for Aging Aircraft**
*Joseph E. Grady, Lewis Research Center*

**The Ground Processing Scheduling System**
*Michael J. Deale, Lockheed Space Operations*

**Reactive Control and Reasoning Assistance for Laboratory Instruments**
*David E. Thompson, Ames Research Center*

**Knowledge From Pictures**
*Walt Truszkowski, Goddard Space Flight Center*

▶ E503

## BIOTECHNOLOGY AND LIFE SCIENCES PART 4

**Optimal Design of Composite Hip Implants**
*D.A. Saravanos, Lewis Research Center*

**Finite Element Analysis of a Composite Artificial Ankle**
*Leigh Ann Perkins, Marshall Space Flight Center; and Blaise E. Czekalski, Intergraph Corp.*

**Design of a Portable Powered Seat Lift**
*Bruce Weddendorf, Marshall Space Flight Center*

**Microcomputer-Based Software for Biodynamic Simulation**
*N. Rangarajan, GESAC Inc.*

▶ E504

## DATA MANAGEMENT, STORAGE, AND PROCESSING PART 2

**The Data Egg: Single-Handed Text Entry Without Positional Constraints**
*Gary L. Friedman, Jet Propulsion Laboratory*

**MIRAGE: The Data Acquisition, Analysis, and Display System**
*Hasan Rahman, General Electric Government Services*

**Tunneling Magnetic Force Microscopy**
*Dr. Edward R. Burke, Laboratory for Physical Sciences*

**The Operator Performance Support System**
*Marlen Z. Conklin and Eugene Walker, Naval Command, Control, & Ocean Surveillance Center*

▶ E505

## MANUFACTURING TECHNOLOGY PART 5

**A New Technology for Manufacturing Scheduling**
*R.S. Hornstein, NASA Office of Space Communications; and J.K. Willoughby, Avyx Inc.*

**Three-Dimensional Laser Window Formation for Industrial Applications**
*Vincent G. Verhoff, Lewis Research Center*

**High-Performance Sapphire Windows**
*Stephen C. Bates, Advanced Fuel Research Inc.; and Larry C. Liou, Lewis Research Center*

**A Dual-Pressure, Ultra-Pure Gas Delivery Vessel Assembly**
*Isaac Maya, Arral Inc.*

▶ E506

## SENSORS AND SIGNAL PROCESSING

**On-Line Process Analysis Innovation: The New Shunting Dielectric Sensor Technology**
*Frank A. Waldman, Axiomatics Corp.*

**A Modular, Programmable Measurement System for Physiological and Spaceflight Applications**
*John W. Hines, Ames Research Center*

**Smart Sensor Method and Apparatus**
*Tom Koger and Vivien Cambridge, Sverdrup Technology Inc.*

**ATTIRE: Analytical Tools for Thermal InfraRed Engineering**
*S. Jaggi, Lockheed Engineering & Sciences*

1:00 - 3:00 pm

**Track #1: University Tech Transfer Opportunities (Part 2)**
*(panelists to be announced)*

**Track #2: International Technology Forum (Part 2)**
*(panelists to be announced)*

*Exhibition Hours:*

12/1—10:00 am - 6:00 pm
12/2—10:00 am - 6:00 pm
12/3—10:00 am - 5:00 pm

# HOW TO REGISTER

Complete the registration form on the next page and mail with check or money order (if applicable) to the Technology Utilization Foundation, or fax it with credit card information to (212) 986-7864. To register by phone, call (800) 944-NASA. Government organizations may use a purchase order to register. **Deadline for preregistration is November 20.** *(See next page for descriptions of registration packages.)*

Preregistrants will receive written confirmations via mail along with their name badge, reception/dinner tickets, and tickets for optional tours (listed below). Badge holders and computerized registration cards must be picked up in person at the Baltimore Convention Center (Pratt Street Lobby) during the following hours:

### ON-SITE REGISTRATION HOURS

| | |
|---|---|
| Monday, Nov. 30 | 9:00 am - 5:00 pm |
| Tuesday, Dec. 1 | 7:00 am - 5:00 pm |
| Wednesday, Dec. 2 | 7:00 am - 5:00 pm |
| Thursday, Dec. 3 | 7:00 am - 4:00 pm |

### SPOUSE & POST-MEETING TOURS

**Tour 1:** Baltimore: Its Sights & Seaport
**Wednesday, Dec. 2, 1992 12:00 - 4:30 pm**
Walking tour begins with lunch at the Chart House Harborside Restaurant, followed by a tour of the USF Constellation and stops at the World Trade Center and Baltimore National Aquarium. **$36 per person.**

Axiom software from T2002 exhibitor NAG Inc. is useful for fractal geometry and chaos studies. This tetrahedron rendered with Axiom illustrates a geometric impossibility--a 3D object with infinite surface area yet no volume!

**Tour 2:** Baltimore City Tour
**Thursday, Dec. 3, 1992 9:00 am - 12:30 pm**
Experience historic Baltimore from the comfort of your motorcoach. Drive by the famous homes of the Otterbein and Federal Hill with stops at the George Peabody Library, the Kirk-Steiff Silversmith's Factory Store, and Fort McHenry. **$18 per person.**

**Tour 3:** Washington, D.C. Post-Meeting Tour
**Friday, Dec. 4, 1992 9:00 am - 5:00 pm**
Just an hour drive by motorcoach to our nation's capital where you will spend a full day visiting government buildings, historic monuments, Arlington National Cemetery, and the Smithsonian Complex. **$25 per person**

Tours will depart from and return to the Baltimore Convention Center. If a tour is sold out or does not meet minimum requirements, your money will be refunded. **Cancellations must be received by November 1, 1992.**

**Questions? Call Wendy Janiel at (212) 490-3999**

### PREREGISTER AND SAVE

| | By 11/20 | On site |
|---|---|---|
| Complete Registration | $240 | $285 |
| Three-Day Symposium/Exhibits | $150 | $195 |
| One-Day Symposium/Exhibits | $75 | $95 |
| Awards Dinner Only | $95 | $105 |
| Exhibits Only | —No Charge— | |

### SPECIAL HOTEL RATES

Book early! Hotel space is limited and requests will be filled on a first-come, first-served basis. Convention rates cannot be guaranteed after October 29, 1992.

| | Single | Double |
|---|---|---|
| Hyatt Regency (headquarters hotel) (800) 233-1234 | $103 | $115 |
| Holiday Inn (301) 685-3500 | $63 | $64 |
| Omni Inner Harbor (800) 843-6664 | $63 | $63 |

When making reservations, you must identify yourself as a participant in the **Technology 2002** conference to receive the special rates.

### CAR RENTAL DISCOUNTS

**Technology 2002** attendees are entitled to a special **AVIS RENT-A-CAR** discount. Please call 1-800-331-1600 and refer to the **Technology 2002** Discount Number: B796477. Discount is valid Nov. 24 - Dec. 11, and includes unlimited mileage.

# TECHNOLOGY 2002

**December 1-3, 1992**
**Baltimore, MD Convention Center**

# REGISTRATION FORM

Your Badge Will Be Printed From This Information:

**NAME** _____

**TITLE** _____

**COMPANY** _____

**ADDRESS** _____

**CITY/ST/ZIP** _____

**PHONE** _____

*Please use a separate form or photocopy for each registrant. Be sure to answer all questions below.*

Which of the following best describes your industry or service? (check one)

A) __ Aerospace
B) __ Electronics
C) __ Computers
D) __ Communications
E) __ Automotive
F) __ Chemicals
G) __ Materials
H) __ Power/Energy
I) __ Biomedical
J) __ Transportation
K) __ Government
L) __ Defense
M) __ Industrial Equip.
N) __ Appliance Manuf.
O) __ Consumer Goods
P) __ Research Lab
Q) __ University
R) __ Consultant
S) __ Library
T) __ Other _____

Your major responsibility is: (check one)

A) __ Management other than engineering
B) __ Engineering management
C) __ Engineering
D) __ Research
E) __ Other (specify)_____

Your principal job function is: (check one)

A) __ General & corporate management
B) __ Design & development engineering
C) __ Engineering services - Tests/ Quality
D) __ Basic Research
E) __ Manufacturing & Production
F) __ Purchasing & Procurement
G) __ Other (specify)_____

Which of these products do you recommend, specify, or authorize the purchase of? (check all that apply)

A) __ Electronic components
B) __ Board-level electronics
C) __ Electronic systems
D) __ Software
E) __ Computers/Workstations/ Peripherals
F) __ CAD/CAE/CAM/CASE
G) __ Mechanical components
H) __ Joining/fastening technology
I) __ Materials
J) __ Plastics & composites
K) __ Ferrous & nonferrous metals
L) __ Ceramics
M) __ Vacuum/cryogenics
N) __ Communications equip./ fiberoptics
O) __ Positioning equip./motion control
P) __ Industrial controls/systems
Q) __ Data acquisition/recorders
R) __ Video/imaging technology
S) __ Sensors/transducers
T) __ Test/measurement instruments
U) __ Lasers/optics
V) __ Laboratory equipment
W) __ Engineering dept. equipment

**FOR FASTEST REGISTRATION**
Fax to (212) 986-7864 or call (800) 944-NASA

**QUESTIONS?**
Call (800) 944-NASA or (212) 490-3999

**OR MAIL THIS FORM TO:**
Technology Utilization Foundation
41 East 42nd Street, Suite 921
New York, NY 10017

**Enter Total $**

**1. COMPLETE REGISTRATION $240** [ ]
Includes admission to **Technology 2002** and National Technology Initiative symposia, workshops, and exhibits for all three show days (Dec. 1-3); a ticket to the Opening Reception on Monday evening, Nov. 30 and to the Technology Transfer Awards Dinner on Wednesday evening, Dec. 2; and a set of the official **Technology 2002** proceedings.

**2. THREE-DAY SYMPOSIA/EXHIBITS $150** [ ]
Covers admission to the symposia, workshops, and exhibits Dec. 1-3.

**3. ONE-DAY SYMPOSIA/EXHIBITS $75** [ ]
Check day(s): __ Tues. (includes NTI) __ Wed. __ Thurs.

**4. AWARDS DINNER ONLY $95** [ ]

**5. EXHIBITS HALL ONLY** FREE
Check day(s): __ Tues. __ Wed. __ Thurs.

**6. SPOUSE/POST-SHOW TOURS** [ ]
__ **Tour 1** - Baltimore Sights & Seaport $36
__ **Tour 2** - Baltimore City $18
__ **Tour 3** - Washington, D.C. $25

**7. PAYMENT ENTER TOTAL PAYMENT DUE** [ ]
Checks must be made out the Technology Utilization Foundation. If you are charging your registration to a credit card, complete the following section.
Check one: __ Master Card __ Visa __ AmEx

CARD NUMBER _____ EXP. DATE _____

SIGNATURE _____ DATE _____

*Registrations and Awards Dinner reservations are transferable and may be cancelled until November 20, 1992 subject to a $50 cancellation fee. After that date no cancellations will be refunded.*

**Return with payment to:**
**Technology Utilization Foundation**
**41 East 42nd Street, New York, NY 10017**

# Stop Reinventing!

Technology 2002 will show you a wealth of ready-made innovations you can apply to solve engineering and design problems.
Reserve your place today!

# Slow-Positron Generator for Studying Polymer Films

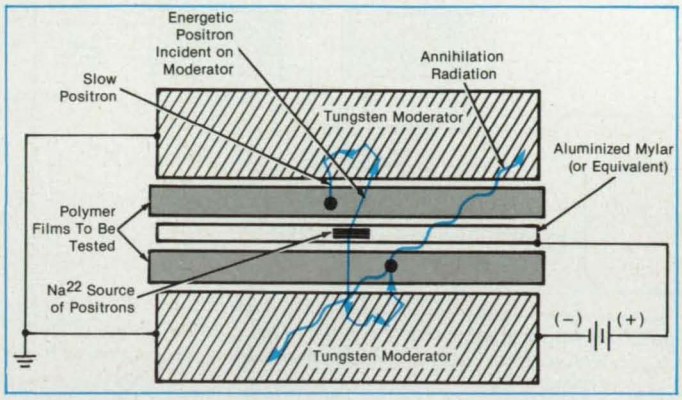
Aspects of molecular structures are probed by positron-annihilation spectroscopy.

*Langley Research Center, Hampton, Virginia*

Polymers are finding increasing applications in the aerospace industry, because of their high strength, light weight, and suitable mechanical, electrical, and optical properties. Some applications call for polymers in the form of thin films. The properties of these films depend strongly on their molecular architecture. Films that have the same chemical composition and density can have different physical properties, depending on their processing histories. It is therefore necessary to develop a technique that can give information about the internal structures of the "finished" thin polymer films. Positron-annihilation spectroscopy (PAS) was previously used to measure free volumes in polymer disks. It was therefore decided to adapt conventional PAS to the study of thin films.

Accordingly, a slow-positron-beam generator was developed for this purpose. It includes an $Na^{22}$ source of positrons and two moderators made of well-annealed, 99.95-percent-pure, 0.0127-cm-thick tungsten foil. As shown in the figure, the two films of the polymer to be tested are inserted between the moderators and an aluminized Mylar (or equivalent) foil that contains the $Na^{22}$ source. Isotropic positron beams penetrate the moderators. After quick thermalization, the incident positron beams suffer multiple elastic scattering from tungsten atoms, forcing some of the positrons to diffuse out of the same side whence they entered each moderator.

Because the work function of positrons in tungsten is negative, positrons that survive annihilation and trapping can eventually diffuse out of it. These positrons can be accelerated to preselected energies by simply applying an appropriate electrical potential difference between the tungsten moderator and the aluminized surfaces of the foil that contains the $Na^{22}$ source. Consequently, all reemitted positrons attracted toward the source foil must pass through the films to be tested. By suitable choice of the potential difference, one can make all positrons emitted from the inner surfaces of the moderators stop in the polymer films to be tested.




**With Proper Choice of Voltage**, positrons emitted by the inward-facing surfaces of the moderators can be made to stop in the polymer films to be tested.

To separate the electron/positron-annihilation spectrum emitted by the moderators from the electron/positron-annhilation spectrum emitted by the films to be tested, it is necessary to make two separate measurements of lifetime. The first measurement is made with the foil that contains the $Na^{22}$ source held at a potential of $-|V|$. The second measurement is made with the source foil held at a much lower potential, such as −10 V. The difference between these two spectra gives the effects of annihilation in the interior of the test polymer films. By measuring the total number of counts in the lifetime spectra with potentials of $\pm|V|$, at the source foil, the efficiency of the slow-positron-beam generator has been calculated to be approximately 6 percent.

The slow-positron-beam generator is suitable for PAS measurements in thin (<0.0254-cm) polymer films. This procedure has been applied to the measurement of free-volume fractions in two polyimide films, PMDA/ODA and ODPA/p-PDA, which is an isomer of PMDA/ODA. Lifetimes of positrons in the polyimide films were measured by use of the standard fast–fast coincidence-lifetime-measurement technique. The results of these measurements show that there are considerable differences between the molecular structures of these two polyimides. Further, this measurement scheme also successfully resolves the difficult timing problem that can be encountered with the positron moderator foils.

*This work was done by Jag J. Singh, and Terry L. St. Clair of* **Langley Research Center** *and Abe Eftekhari of Analytical Services & Materials, Inc. Further information may be found in:*

*NASA TM-101590 [N89-25433], "A Slow Positron Beam Generator for Lifetime Studies," and*

*NASA TP-3074 [N91-22538], "Low Energy Position Flux Generator for Microstructural Characterization of Thin Films."*

*Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14250.*

# Liquid-Arc/Spark-Excitation Atomic-Emission Spectroscopy

Constituents of solutions can be identified in situ.

*John F. Kennedy Space Center, Florida*

Liquid-arc/spark-excitation atomic-emission spectroscopy (LAES) is an experimental variant of atomic-emission spectroscopy in which an electric arc or spark is established in a liquid and the spectrum of the light from the arc or spark is analyzed to identify chemical elements in the liquid. In general, in atomic-emission spectroscopy, it is necessary to vaporize speci-

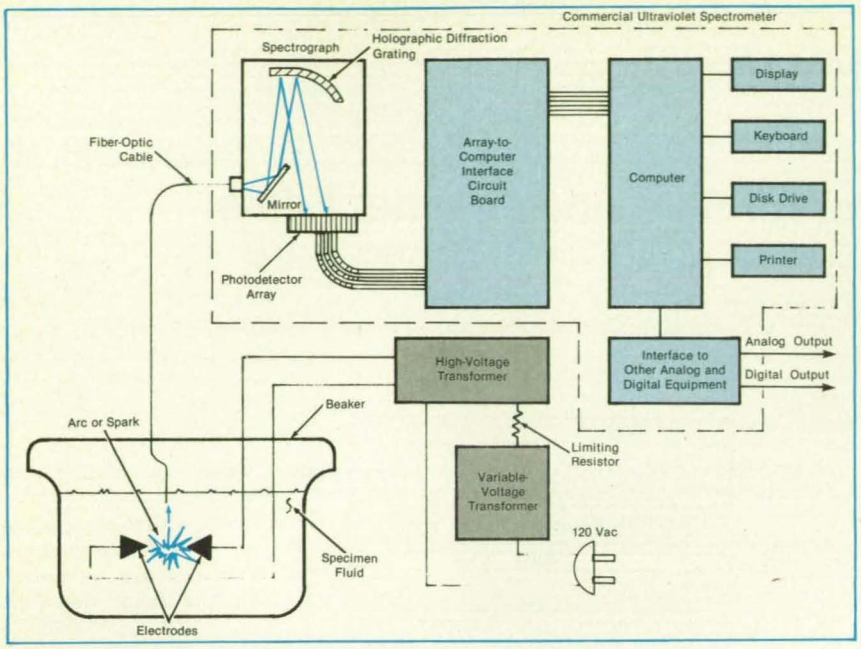



Figure 1. The **Prototype LAES Apparatus** used in the initial experiments was improvised by using a beaker equipped with a spark gap as the specimen cell in conjunction with a commercial ultraviolet spectrometer.

mens to break the bonds between atoms and to put in energy to excite emissions; the energy for vaporization and excitation can be supplied by flames, arcs, sparks, and other means.

Heretofore, it has been necessary to prepare solid and liquid specimens for subsequent spectral analysis; e.g., by extraction of small amounts of liquid from process streams. A principal advantage of LAES is that when fully developed, it should make such extraction unnecessary in many cases: the spark or arc could be lit directly in the batch or stream of liquid to be analyzed. In particular, flowthrough cells equipped with suitable windows and electrodes could be used in online LAES monitoring of the constituents of process streams.

In the initial experiments, arcs were established between electrodes in a beaker filled sequentially with various solutions containing metal ions, the concentrations of which were to be monitored spectroscopically. Light from the arcs was conducted through a fiber-optic cable to a Biotronics ultraviolet/visible/absorption/emission array spectrometer that was operated in the emission mode (see Figure 1).

The physical mechanisms that give rise to the emitted light are not yet understood in detail; it has been conjectured that the arc or spark gives rise to a pocket of gaseous plasma within the liquid. In any event, the spectral lines of ions dissolved in the solutions were observed in the initial experiments, and the intensities of these lines depended upon concentrations (see Figure 2). These observations provide encouragement for the development of LAES equipment for online monitoring of process streams in such industries as metal plating, electronics, and steel, and for online monitoring of streams that could affect the environment.

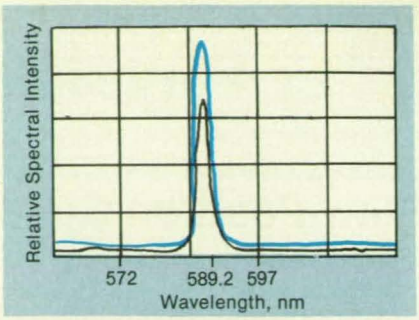



Figure 2. These **Atomic-Emission Spectra of Sodium** were measured by LAES in two solutions that contained sodium in different concentrations. In both cases, spectral peaks at the characteristic sodium wavelength of 589.2 nm were clearly visible.

*This work was done by Kenneth J. Schlagen of Biotronics Technologies, Inc., for* **Kennedy Space Center**. *For further information, Circle 46 on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center [see page 20]. Refer to KSC-11540.*

# Irradiation by Neutrons and Annealing of SiGe Alloys

## Heat treatment restores thermoelectric performance that has deteriorated under irradiation by neutrons.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

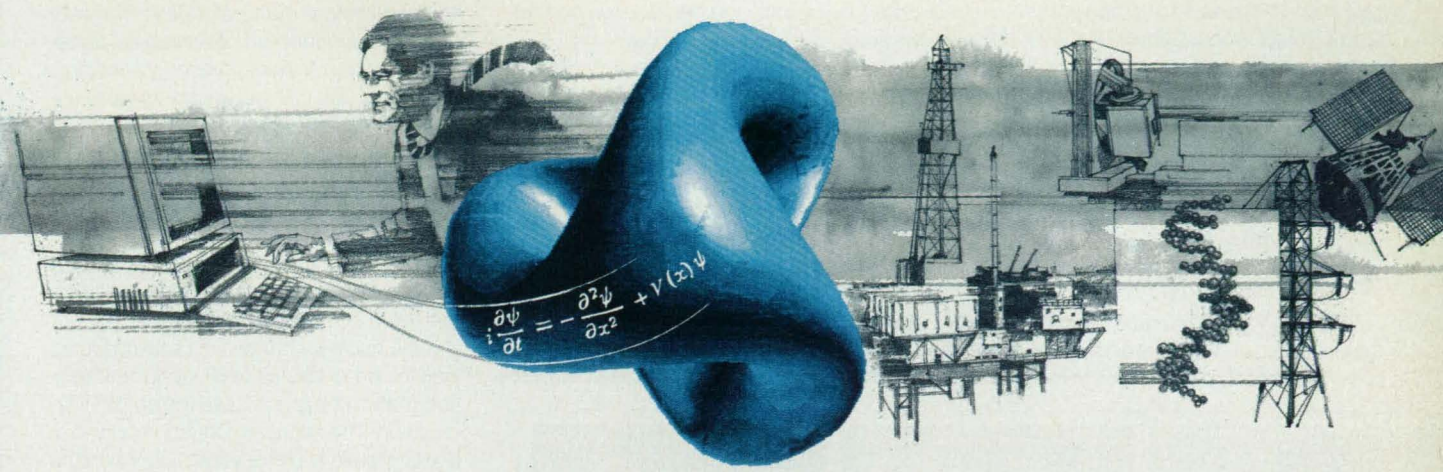
Experiments have shown that heat treatment at a temperature of 1,000 °C restores the thermoelectric properties of zone-leveled and hot-pressed n- and p-doped $Si_{80}Ge_{20}$ alloys that have deteriorated under irradiation by fast neutrons at fluences up to $5.4\times10^{19}$ $cm^{-2}$. This discovery suggests that these SiGe materials can be used in radioisotope thermoelectric generators and other applications up to this fluence and operating at temperatures of 600 to 1,000 °C.

In the experiments, 12.6-mm-diameter specimens of the SiGe alloys were irradiated with neutrons at thermal-neutron fluences up to $1.8\times10^{20}$ $cm^{-2}$ and at fast-neutron fluences up to $5.4\times10^{19}$ $cm^{-2}$. The sizes of the grains in the hot-pressed specimens ranged from 1 to 10 $\mu$m compared to at least several millimeters in the zone-leveled specimens. Also, the hot-pressed samples contained about 2 atomic percent of oxygen compared to very little in the zone-leveled specimens. The carrier concentrations and mobilities of charge carriers (and, hence, the electrical resistivities) in the specimens were measured at room temperature in a Hall-effect apparatus, while the thermal diffusivities of the specimens were measured in a flash diffusivity apparatus at 177 to 192 °C, both before and after the irradiation and after each subsequent 2-h heat treatment at 350 °C, 600 °C, and 1,000 °C.

The irradiation was found to increase the electrical resistivities significantly (by factors ranging from about 50 to $3\times10^4$ at the highest fluence used), but the thermal conductivities decreased by only about 10 to 15 percent. This suggests that the radiation produced only small defects (single pairs and small chains of vacancies).

The 350-°C and 600-°C heat treatments each restored the thermoelectric properties only partially. However, the 1,000-°C heat treatment restored all the properties to almost exactly their original "reset values." There thus appears to be no evidence of permanent extended defects, and neither grain boundaries nor oxygen atoms appear to have acted as traps or nucleation sites for permanent extended defects.

*This work was done by Jan W. Vandersande, Joseph McCormack, and Andrew Zoltan of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 53 on the TSP Request Card. NPO-18313*

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## Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

## Tables of Gaussian-Type Orbital Basis Functions

### Sets of basis functions are optimized with respect to energy.

This NASA technical memorandum contains tables of estimated Hartree–Fock wave functions for the atoms lithium through neon and potassium through krypton. The sets contain the optimized Gaussian-type orbital exponents and coefficients, and are of near Hartree–Fock quality.

The orbital exponents were optimized by minimizing the restricted Hartree–Fock energy via a scaled Newton–Raphson scheme in which the Hessian is evaluated numerically by use of analytically determined gradients. Each set of basis functions was optimized until the energy was stationary to at least $1\times10^{-8}$ Hartrees, $E_H$, and the virial ratio differed from 2 by less than $1\times10^{-8}$. While a virial ratio of 2 is not a sufficient condition for a minimum, it is a sensitive measure of convergence in the procedure for optimization of the exponent. The energy is usually stabilized well before the virial ratio is. The sets of basis functions are believed to correspond to nearly-minimum-energy solutions.

The starting orbital exponents were selected in the following order of preference. First to be selected were derived sets in which the exponents are taken from other optimized sets for the same atom and state. The improvement in energy upon further optimization is minimal. Second, optimized sets for other atoms with similar spatial extent were scaled by the ratio of $Z^2$, where $Z$ is the nuclear charge. This scaling works well for Be to Ne, Ga to Kr, and the transition-metal atoms that have the same *s* occupation. The improvement upon optimization is generally small, especially when the set of basis functions for adjacent atoms in the periodic table is scaled. Third, one function was added to each symmetry in which the inner functions are specified by ratios given in a previous related NASA technical memorandum (TM-89449) by the same author. This procedure works well except where the number of functions that describe the valence shell increases, say from double zeta to triple zeta and where there is a sizable gap between the valence and outer-core exponents. Fourth, scaled sets of basis functions are extended with even-tempered functions.

The most accurate sets of basis functions reported for Li through Ne are (18*s* 13*p* )sets, which are within $4\times10^{-6}\ E_H$ of the numerical Hartree–Fock results. For B to Ne, sets with more than 15*s* functions are quadruple zeta in the valence space. For the transition metal-atoms, the 20*s*12*p* 9*d*) basis sets are triple zeta in the valence space and are approximately equivalent to Clementi and Roetti's accurate Slater-type-orbital sets. Supplementing the (20*s* 12*p*9*d*) basis sets optimized for the lowest state with the $4s^2 3d^n$ occupation with a diffuse *d* function gives self-consistent-field energy separations to the $4s^1 3d^{n+1}$ and $3d^{n+2}$ states that are within $10^{-4}\ E_H$ of the numerical Hartree–Fock results. The most accurate basis sets for the transition-metal atoms are within $3\times10^{-5}\ E_H$ of the numerical Hartree–Fock results. In addition, energy-optimized sets are reported for He($^3P$), Li($^2P$), and Be($^3P$).

*This work was done by Harry Partridge of* **Ames Research Center**. *Further information may be found in NASA TM-101044 [N89-26057], "Near Hartree–Fock Quality Gaussian Type Orbital Basis Sets for First- and Third-Row Atoms."*

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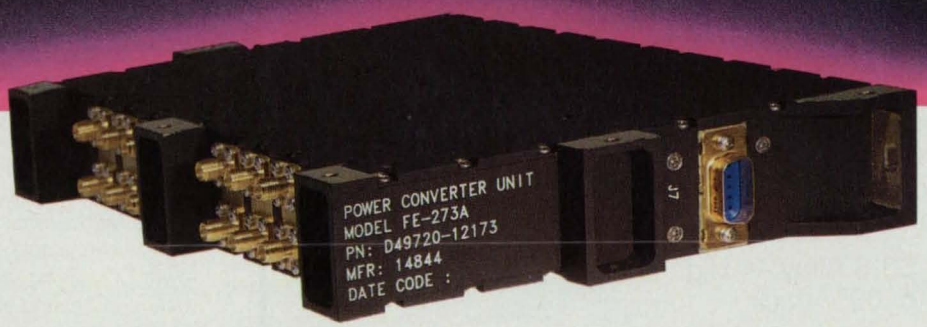


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## Nonequilibrium Effects in Hypervelocity Flow

Chemistry and heat transfer are analyzed.

A report presents a theoretical analysis of chemical and thermal nonequilibrium phenomena in the stagnation region of a blunt body traveling through a sparse atmosphere at many times the speed of sound. The investigation is motivated by the need to predict the rate of heat transfer to an aeromaneuvering orbital-transfer vehicle.

The study involves speeds of about 10 km/s, an atmosphere representing an altitude of about 80 km, and body radii of 1 to 50 cm. The analysis employs a continuum-theory approach and is based on the viscous-layer and incipient-merged-layer regimes of rarefied flow. The mathematical model of the gas includes two molecular species, with both translational and vibrational temperatures (rotations are assumed to be in thermal equilibrium with translations).

A simplified version of the Navier–Stokes equations is used to treat the viscous flow in the thin shock layer. These are augmented by the equations for the conservation of total energy, chemical species, and vibrational energy; the equation of state; expressions for the total enthalpy of the mixture, the static enthalpy of the mixture, and the enthalpy of each species; and the relation between the vibrational energy and temperature of each species. To reduce the number of equations, the gas is considered to consist only of nitrogen atoms and molecules: this also reduces the number of chemical reactions that have to be considered, leaving only

$$N_2 + N \rightleftarrows N + N + N$$

and

$$N_2 + N_2 \rightleftarrows N + N + N_2$$

The equations are converted into a set of boundary-layer-like equations by a set of integral transformations. A stream function is introduced to satisfy requirements of continuity. No-slip boundary conditions are imposed at the surface of the body. The concentration of atoms at the surface is assumed to obey a linear reaction law that includes a surface-catalytic recombination rate. Shock-slip conditions are imposed at the edge of the shock layer.

The equation for the rate of transfer of heat at the surface requires the estimation of some thermodynamic and transport properties. The viscosity is expressed as a power-law function of temperature, the thermal conductivities are expressed in terms of the Prandtl numbers, the specific heats at constant pressure are evaluated from kinetic theory, and the specific heat for the vibrational energies of the molecules is derived from the equations for the vibrational energies as functions of the vibrational temperatures.

A vibrational-nonequilibrium expression is used to estimate the rate of molecular dissociation. A modified relaxation equation describes the exchange of energy between the translational and vibrational modes.

The equations are solved numerically with iterative treatment of nonlinear terms. In general, the solutions vindicate the nonequilibrium approach in that they differ from equilibrium predictions. Preliminary results suggest that the inclusion of the vibrational-relaxation time has little effect on the heat-transfer rate at a fully catalytic surface. However, vibrational nonequilibrium may increase the rate of transfer of heat to a noncatalytic surface, depending on the degree of nonequilibrium.

*This work was done by Kevin G. Brown of* **Ames Research Center**. *To obtain a copy of the report, "Chemical and Thermal Nonequilibrium Heat-Transfer Analysis for Hypervelocity, Low Reynolds Number Flow," Circle 71 on the TSP Request Card. ARC-11760*

## Mode/Medium Instability in $CO_2$ Laser

The instability can be reduced by a mirror with a Gaussian reflectivity profile.

A report describes a theoretical study of the mode/medium instability (MMI) in a $CO_2$ laser. The purposes of the study are (1) to extend, to small Fresnel numbers, a previous study of MMI that was restricted to large Fresnel numbers and (2) to study methods, suggested by authors of previous studies, to suppress the MMI. The method of primary interest involves replacement of a hard (that is, abrupt)-edge output mirror in the laser resonator with a mirror, the local reflectivity of which decreases with radial distance from the optical axis according to a Gaussian profile.

The MMI is caused by the vibrational-to-translational relaxation of the upper and lower $CO_2$ lasing levels, which relaxation results in heating at a rate that depends on the local intensity of radiation in the laser resonator cavity and that is greatest where the intensity is highest. The uneven rate of heating in an unstable laser resonator with hard-edge output mirror is attributed mainly, although not wholly, to the variations in intensity caused by diffraction from the hard edge. The uneven rate of heating leads to acoustic perturbations of density and, thus, spatial and temporal variations in the permittivity that, in turn, cause the radiation to be diffracted even more. The resulting changes in intensity cause more variations in the rate of heating, completing the feedback cycle. The overall result is that the quality of the out-

put beam deteriorates with time; if the laser pulse has sufficient intensity and duration, the quality of the beam can be destroyed completely. Thus, the MMI is of major importance in the design of high-power, long-pulse $CO_2$ lasers.

The study begins with the basic equation for the permittivity of the $CO_2$ lasing medium and with the equations that describe the relationships among the permittivity, the gain, the rate of heating, the density of the gas, the intensity of the radiation, the frequency of the radiation, and the propagating electric field. The permittivity and gain are approximated as being spatially constant within each of a number of disks, called "gain sheets," oriented transversely to the optical axis. Maxwell's equations and the equation for the density of the gas are solved in one transverse dimension and in the longitudinal dimension with the gain sheets. The equations are solved numerically by an iterative technique to obtain the evolution, with time, of the laser beam as it is affected by the MMI.

Solutions are obtained for a range of such parameters as the Fresnel number and the density of the gas. The results show that the mode of an unstable resonator with hard-edge mirror deteriorates because of the diffraction ripples in the mode. Decreasing the density of the gas is found to improve the quality of the beam and prolong its life, but at the expense of peak power. The results also show that an output mirror with a Gaussian reflectivity profile produces a smoother intensity profile, which, in turn, significantly reduces the effect of the MMI.

*This work was done by K. L. Webster and C. C. Sung of* **Marshall Space Flight Center**. *Further information may be found in NASA TP-3023 [N90-25673], "Mode-Medium Instability and Its Correction With a Gaussian Reflectivity Mirror."*

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*MFS-27250*

## Accuracy of the Correlated-*k* Method

### The method is accurate enough for mathematical models of irradiance and climate.

A report discusses the accuracy of the correlated-*k* method of calculating spectral radiances of vertically nonhomogeneous atmospheres. The correlated-*k* method involves an approximation in which (1) small spectral intervals for which the average spectral radiances or absorption coefficients are nearly equal to a given value,

$k$, are grouped together and (2) the frequency is replaced by a new independent variable, $g$, which is a cumulative distribution function that is a monotonic function of $k$.

The principal advantage of the correlated-$k$ method is that it reduces the number of arithmetic operations and the size of computer memory required to compute spectral irradiances. It is especially useful where emission or absorption spectra are complicated by many lines and/or sharply varying continua, both of which would otherwise require many more data for accurate characterization by the more nearly exact "line-by-line" technique (straightforward representation of frequency- or wavelength-dependent quantities by averages of those quantities within frequency or wavelength intervals as fine as are necessary to resolve all spectral details to acceptable accuracy).

The report presents a brief description of the correlated-$k$ method. Next it discusses some theoretical considerations, showing that the correlated-$k$ method can, in principle, be correct when applied to (1) weak spectral lines, (2) strong, pressure-broadened spectral lines, (3) spectral lines affected by Doppler shifts at constant temperatures, and (4) overlapping spectral bands.

Noting the absence of a universally applicable, underlying theory, the report then turns to numerical examples to evaluate the accuracies of correlated-$k$ computations by comparisons with line-by-line computations of scattering and absorption in atmospheres that contain $CO_2$, $H_2O$, and $O_3$. From the numerical results, the authors draw the following conclusions:

- The order of magnitude of errors in the correlated-$k$ method is 1 percent. This is sufficiently accurate for the calculation of most radiation quantities of interest.
- Errors much larger than 1 percent occur only when radiative quantities are very much smaller than their average values. These errors can be greatly reduced by methods described in "Transformations for Atmospheric-Radiation Calculations" (NPO-18026), *NASA Tech Briefs*, Vol. 15 No. 7, page 42, 1991.
- Errors do not depend systematically on gas molecules, distributions of gases and aerosols, or the optical properties of aerosols.
- Errors do not increase systematically with the order in which certain differences are computed.
- The transmission by overlapping bands can be incorporated into the correlated-$k$ method via a multiplicative property.
- The effects of temperature can be interpolated on a coarse grid.
- Ten quadrature points are often sufficient to average over complex spectral intervals that contain thousands of lines.
- The correlated-$k$ method is well suited to iterative methods involved in the inversion of satellite radiances or in numerical models of weather or climate.

*This work was done by Richard Goody, Robert A. West, Luke Chen, and David Crisp of Caltech for* **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "The Correlated-k Method for Radiation Calculations in Nonhomogeneous Atmospheres," Circle 20 on the TSP Request Card. NPO-18020*

## Ties Between Celestial and Planetary Reference Frames

### A new determination of the radio-planetary frame tie has improved accuracy.

A report presents a new determination of the relative orientation (or frame tie) between the reference frame of extra-galactic radio sources (e.g., quasars) and the reference frame of the planetary ephemeris. The radio reference frame is defined by the positions of very distant radio sources as determined by Very Long Baseline Interferometry (VLBI). The planetary reference frame is defined by the ephemeris of the solar system, especially the orbit of the Earth. Both the radio and planetary reference frames are inertial and internally consistent to a few milliarcseconds or better. The relative orientation between the two frames is not known to the same accuracy. The frame-tie uncertainty is an important systematic error source for interplanetary spacecraft-orbit determination, which uses radio measurements of spacecraft position and velocity to determine trajectories with respect to the solar system ephemeris. Previously, the frame-tie was determined to 30 milliarcseconds by radio measurements of spacecraft in orbit about Venus and Mars.

The method employed for the improved frame-tie estimate relies on the ability to measure the orientation of the Earth with respect to an inertial reference frame. The orientation of the Earth is measured with respect to the radio reference frame by VLBI. The Earth's orientation with respect to the planetary reference frame is measured by Lunar Laser Ranging (LLR). (LLR measures the Earth rotation with respect to the lunar ephemeris, which is sensitive to the planetary ephemeris through solar perturbations on the Moon's orbit). Both VLBI and LLR measure Earth orientation with accuracy better than 5 milliarcseconds. The relative orientation of the celestial reference frames can then be determined by comparing the VLBI and LLR Earth-orientation results and the VLBI and LLR station locations, which are also estimated by their respective measurement techniques.

The new frame-tie determination is derived from a comparison of Earth-orientation results based on VLBI measurements from NASA's Deep Space Network (DSN), with stations in California, Spain, and Australia, and on LLR measurements made at stations in Texas, Hawaii, and France. The relative orientation of the DSN and LLR station locations is made possible by a combined station set from the Crustal Dynamics Project (CDP), which contains both the DSN and LLR station locations. As a byproduct of determining the relative orientation of the DSN and LLR station locations, the geocentric origin of the LLR stations can be applied to the VLBI-derived DSN station locations (which are insensitive to the geocenter) to produce accurate ($\approx$ 10 cm) geocentric locations for the DSN stations.

The radio-planetary frame tie determined by comparing the DSN VLBI and LLR Earth orientation results and station locations has an estimated accuracy of 5 milliarcseconds in all three rotation directions and represents an improvement over the previous frame tie determination with 30-milliarcsecond accuracy. The new frame-tie determination should lead to improved orbit determination for interplanetary spacecraft.

*This work was done by Mark H. Finger and William M. Folkner of Caltech for* ***NASA's Jet Propulsion Laboratory****. To obtain a copy of the report, "A Determination of the Radio-Planetary Frame Tie and the DSN Tracking Station Locations," Circle 4 on the TSP Request Card.*
*NPO-18328*

## Lightning-Sensor Data Help in Understanding Thunderstorms

### Data from a network of magnetic sensors are used in diagnosis and prediction.

A NASA technical memorandum discusses research on the use of data from a network of ground-based magnetic direction-finding ground-strike lightning sensors to diagnose and predict the occurrence and evolution of thunderstorms. The purposes of this study are to explore the applicability and limitations of extrapolation techniques used to generate forecasts from these data; to examine physically-based, nonlinear mathematical models for applicability to the lightning-forecast problem; and to determine the valid extrapolation ranges of such models for various weather scenarios.

Of the models considered, the one selected to represent the growth and decay of thunderstorms is a three-parameter nonlinear one called the "logistic" model, which has been used before to represent such phenomena as chemical kinetics and the growth of populations. According to the logistic model, the rate of growth of the observed quantity, $y$ (e.g., the number of lighting flashes), is proportional to the quantity and to the remaining possible growth of the quantity (e.g., a limiting value of lightning activity that depends on the energy available in the environment). The logistic model yields a sigmoid growth curve, $y = \alpha/(1+\beta\, e^{-kt})$, where $t$ is time and $\alpha$, $\beta$, and $k$ are the three parameters.

The report contains seven chapters. Chapter 1 is an introduction that presents a recent history and overview of thunderstorm-forecasting technology. Chapter 2 discusses the lightning and precipitation time series of storm systems over a wide range of space and time scales. The results of analyses of these data are used to develop a conceptual understanding of the life cycles of thunderstorms. The logistic model is offered as a candidate model of the thunderstorm life cycle.

Chapter 3 discusses the process of finding the most accurate locations of cloud-to-ground lightning discharges. This process involves the removal of systematic errors from the data and the application of an optimization technique to locate the most probable position of each lightning discharge. A novel approach to the removal of systematic errors involves the use of isolated radar echoes.

Chapter 4 presents a pattern-recognition scheme that is used to generate initial seeds or "first-guess" fields for cluster-

ing the discrete lighting discharges into storm cells. The clustering process is critically dependent on the prior accuracy of the estimated locations of lightning discharges. The generation of subsequent storm-life-cycle time series relies on the assignment, via this cluster-analysis procedure, of the correct number of lightning discharges to the proper storms (groups). The advantages and limitations of different clustering strategies for the identification and tracking of storms are examined. The identification of storms from lightning data alone is compared with the identification of storms from radar alone, and some synergies for the fusion of lightning and radar data are explored.

In Chapter 5, the logistic model is used to examine the storm life cycle over a wide range of space and time scales and to address the potential of nonlinear regression models to improve upon short-term forecasts. A physical interpretation of the parameters of the logistic model and the resulting implications for determining the valid extrapolation range are considered.

Chapter 6 summarizes the chief results of this research and discusses how these results move the state of knowledge forward. Chapter 7 recommends future research.

*This work was done by Steven J. Goodman of* **Marshall Space Flight Center**. *Further information may be found in NASA TM-103521 [N91-15660] "Predicting Thunderstorm Evolution Using Ground-Based Lightning Detection Networks."*

*Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. MFS-27263*

## Aspects of 40- to 50-Day Oscillations in LOD and AAM

### Data suggest the existence of a seperate midlatitude oscillation.

A report presents a study of fluctuations in the rotation of the Earth, focusing on irregular intraseasonal oscillations in the length of day (LOD) and atmospheric angular momentum (AAM) with periods that vary from 40 to 50 days. This study draws upon and extends the results of prior research in which separate aspects of the well-known tropical and of the novel midlatitude oscillations were discovered and found to be linked by exchanges of angular momentum between the atmosphere and the rest of the Earth.

Three possible mechanisms for the origin of 40- to 50-day oscillations have been proposed. The so-called Madden–Julian (MJ) mechanism connects these intraseasonal LOD and AAM oscillations to eastward-propagating anomalies in tropical convection and zonal wind, first documented by Madden and Julian in 1971 and 1972. Another hypothesis, formulated by Ghil and associates, relates the oscillation to an instability of the nonzonal westerly flow caused by the interaction of the jet stream with mountains in the mid-latitudes. The dominant period of this instability in a simplified, equivalent-barotropic model of the atmosphere is near 40 days; however, for realistic parameter values, it has aperiodic, intermittent behavior, which would explain the broadband nature of the AAM/LOD oscillations. The third mechanism, proposed by Simmons, Wallace, and Branstator, links these oscillations to disturbances, which derive their energy from the basic state through barotropic instability. In this theory, topography contributes only to the maintenance of asymmetries in the climatological basic state, and is absent from the instability mechanism itself; in the second approach, topography interacts both with the basic flow and with its oscillatory instability.

In this study, the nature and origin of the 40- to 50-day oscillations are investigated via a combined analysis of AAM data computed by an operational analysis of meteorological data from the National Meteorological Center (NMC) and LOD data from space-geodetic measurements for the 12-year interval from 1977 through 1988. The NMC-based AAM data are analyzed by latitude belts, with reference to two additional sets of AAM data simulated by mathematical models of global atmospheric circulation that do not reproduce MJ oscillations in the tropics. One simulation includes a realistic description of topography; in the other simulation, the surface of the Earth is regarded as smooth. The analysis of these simulations enables the evaluation of hypotheses concerning topographic and barotropic instabilities in the absence of the MJ oscillation.

The analysis leads to the conclusion that there are two distinct oscillations in the exchanges of angular momentum within the atmosphere/Earth system: one has a period of about 50 days; the other, a period of about 40 days. The 50-day oscillation is found to be associated with tropical variations in zonal wind, probably related to the MJ mechanism. The 40-day oscillation is tentatively attributed to interactions between nonzonal flow and mountains in the northern mid-latitudes.

*This work was done by Jean O. Dickey and Steven L. Marcus of Caltech for* **NASA's Jet Propulsion Laboratory** *and by Michael Ghil of UCLA. To obtain a copy of the report, "Extratropical Aspects of the 40-50 Day Oscillation in Length-of-Day and Atmospheric Angular Momentum," Circle 35 on the TSP Request Card.*
*NPO-18378*

# Superconducting Films on Microwave Dielectric Substrates

Vapor-deposited layers of Cu, $BaF_2$, and Y are annealed in oxygen.

*Lewis Research Center, Cleveland, Ohio*

Thin films of the superconductor $YBa_2Cu_3O_{7-\delta}$, which has a high critical superconducting-transition temperature ($T_c$), have been formed on microwave dielectric substrates of $SrTiO_3$, MgO, $Al_2O_3$ coated with $ZrO_2$, and $LaAlO_3$. The films were formed by repeated sequential deposition of layers of Cu, $BaF_2$, and Y in an electron-beam evaporator, followed by annealing in oxygen. For most depositions, the 3-layer sequence of Cu/$BaF_2$/Y was repeated 4 times to obtain a total of 12 layers. The deposition technique employed gives the layers the uniformity and reproducibility required for the fabrication of microwave circuits.

After deposition of the multilayer on each substrate, the resulting specimen was annealed for 15 min to 3 h at a temperature between 850 and 900 °C in high-purity flowing oxygen. To remove fluorine from the films, the oxygen was humidified by bubbling it through water before introducing it into the annealing furnace. After slow cooling at −2 °C/min, the specimens were annealed at 450 °C in dry oxygen for 6 h, then cooled to room temperature at −2 °C/min.

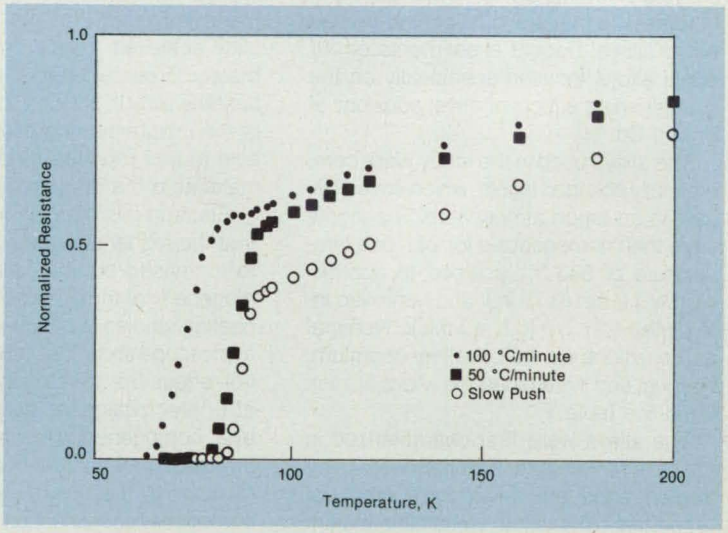
Silver ohmic contacts for four-probe electrical measurements were formed on the films by evaporation followed by annealing at 500 °C. The films were characterized by resistance-vs.-temperature measurements. The criterion for $T_c$ was the decrease of resistivity to the noise level of approximately $10^{-9}$ Ω•cm. The specimens were also characterized by energy-dispersive x-ray spectroscopy, x-ray diffraction, and scanning electron microscopy.

The time and temperature parameters of the annealing cycle and the compositions of layers were found to influence strongly the superconducting properties of the completed films. With $SrTiO_3$, the highest $T_c$ was achieved with composition ratios Cu/Y = 3.00 and Ba/Y = 2.25, an intermediate heating rate of 50 °C/min, and a 45-min anneal at 900 °C. The films of MgO and $Al_2O_3$ have to be annealed at lower temperatures for longer times. With MgO, a $T_c$ of 70 K was achieved with composition ratios Cu/Y = 2.88 and Ba/Y = 2.04 and a 3-h anneal at 850 °C. With $Al_2O_3$, a $T_c$ of 72 K was achieved with composition ratios Cu/Y = 3.10 and Ba/Y = 1.88 and a 3-h anneal at 850 °C.

Microstrip ring resonators are being fabricated from superconducting films on $LaAlO_3$ and MgO substrates by lift-off lithography. The microwave properties of these resonators are to be tested at a frequency of 30 GHz. $LaAlO_3$ is particularly interesting as a substrate material because it has a crystal structure comparable to that of $SrTiO_3$, but has significantly better microwave properties. The best films were formed on $SrTiO_3$, on which a $T_c$ of 85 K was achieved. On $LaAlO_3$, a $T_c$ of 80 K was achieved (see figure).

*This work was done by J. D. Warner and K. B. Bhasin of* **Lewis Research Center** *and G. J. Valco and N. J. Rohrer of Ohio State University. Further information may be found in NASA TM-102068 [N89-23791], "Sequentially Evaporated Thin Y-Ba-Cu-O Superconducting Films on Microwave Substrates".*

*Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-15011*




The **Normalized Resistances** as functions of temperature are plotted for 0.5 μm-thick superconducting films made from deposited layers that had the composition ratios Cu/Y = 3.00 and Ba/Y = 2.25 on $LaAlO_3$. Prior to the 45-min anneal at 900 °C, each film was introduced into a cold furnace and heated at a rate of 50 °C/min or 100 °C/min, or else was given a slow (5-min) push into the furnace preheated to the annealing temperature.

# Polyphosphazene Icephobic Coating Materials

Polyphosphazenes offer increased anti-icing effectiveness and durability.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Coating materials consisting mostly of modified polyphosphazene (Class FZ) elastomers provide better protection against icing than do fluorocarbon polymers and silicone elastomers. These new icephobic coats can reduce the accumulation of ice on aircraft, radomes, antennas, ships, and power-transmission lines. The weight of such accumulations of ice has led to airplane crashes and to fallen power lines.

An icephobic coat reduces the adhesive force between ice and a surface. As a consequence, the increasing weight of the ice, wind loading, or vibration of the surface causes the ice to be shed.

Studies of icephobic response have shown that materials with low surface tension alone (for example, polytetrafluoroethylene) are insufficiently icephobic and that a rubbery material (for example, silicone) is more effective. An effective icephobic material should combine low surface tension with a low modulus of elasticity (i.e., a rubbery character). Phosphazene elastomers possess these desired properties and, in addition, have low glass-transition temperatures, good environmental stability, curability, and moderate cost.

The raw phosphazene polymer used in an experimental study of icephobic coating materials has a surface tension of approximately 15 dynes/cm and modulus of elas-

ticity of 1,000 psi (7 MPa); it can be formulated as an icephobic coating material by the addition of other polymers, reactive compounds, and initiators. Possibilities for coating additives include vinyl-terminated siloxanes, acrylic monomers, and unsaturated urethanes or polyesters. Other compounds that react with phosphazene might also be used.

The monomer/additive mixtures can be cured by heating or by use of such chemical initiators as Michler's ketone in the presence of ultraviolet light. In addition, an interpenetrating-network polymer (IPN) can be made from a blend of the phosphazene elastomer with isocyanate (urethane) prepolymers. These compounds then cure upon exposure to moisture, trapping and bonding the phosphazene to the coated surface. Physical properties can be varied over a wide range by use of either coreaction or IPN-type cures, and silane coupling agents bond the coat to the coated surface.

*This work was done by Paul B. Willis of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 51 on the TSP Request Card.*
*NPO-18110*

# Indium Helps Strengthen Al/Cu/Li Alloy

Heat treatment alone, unaccompanied by cold work, can strengthen the alloy.

*Langley Research Center, Hampton, Virginia*

The desire for aluminum alloys for use in lightweight structural components in aircraft has spurred serious interest in the development of Al/Cu/Li alloys of lower density. Increased strengths have been developed in these alloys through the combined effects of cold-working and heat treatments. However, in the fabrication of some structural parts, one cannot use cold work to achieve full potential strengths. In these cases, it is desirable to have an alloy capable of attaining maximum strength through heat treatment alone. Previous research showed that minor additions of the alloying elements Cd, In, or Sn resulted in increases in the strengths of heat-treated Al/Cu alloys. Recent experiments on Al/Cu/Li alloys focused specifically on the strengthening effects of minor additions of In and Cd.

The alloys used in the study were commercially obtained ingots, which were chill-cast in an argon atmosphere. The ingots were then homogenized for 24 h at a temperature of 543 °C, scalped to approximately 1.9 cm (0.75 in.), and hot-rolled into plates 1.27 cm (0.5 in.) thick. Nominal compositions for the baseline, cadmium-bearing, and indium-bearing alloys are listed in the table 1.

The alloys were first characterized in the as-received state; then they were heat-treated, aged, and tested for a variety of properties. The alloy containing indium was found to have increased age-hardening response in the T6 condition. This alloy attained a peak hardness greater than that of the baseline material for aging temperatures ranging from 160 to 190 °C. Tensile tests on peak-aged specimens indicated that the indium-bearing alloy achieved a yield strength approximately 15 percent higher than that of the baseline alloy. In addition, the yield strength of the indium-bearing alloy was comparable to that reported for similar baseline material in the T8 condition.

| Alloy | Element | | | | | | |
|---|---|---|---|---|---|---|---|
| | Cu | Li | Zr | Fe | Cd | In | Al |
| 59802 (Cd-Bearing) | 2.64 | 2.43 | 0.14 | 0.08 | 0.14 | — | Balance |
| 59803 (In-Bearing) | 2.49 | 2.39 | 0.15 | 0.07 | — | 0.18 | Balance |
| 59373 ("Baseline" Alloy) | 2.29 | 2.31 | 0.18 | 0.08 | — | — | Balance |

The **Compositions of Three Tested Alloys**, as received, are listed in weight percentages.

Electron-microscopy studies indicate that the higher strengths are attributable to increased number densities and homogeneity of the $T_1$ and $\theta'$ phases. In situ heating studies in a high-voltage electron microscope show that indium additions do not affect the heterogenous nucleation of $T_1$ precipitates at dislocations. However, homogeneous nucleation of $T_1$ is increased in the indium-bearing alloy, suggesting that the indium additions promote homogeneous nucleation by reducing the precipitate/matrix interfacial energy of $T_1$. Further analyses indicated that there were no discernible differences between the precipitate and interfacial structures of the $T_1$ and $\theta'$ phases of the indium-bearing alloy on the one hand and those of the baseline alloy on the other hand.

The indium-bearing alloy combines low density with the ability to achieve high strength through heat treatment alone. This alloy would be highly suitable for processing to produce parts of nearly net shape, with particular applications in aircraft and aerospace vehicles.

*This work was done by Linda B. Blackburn of* **Langley Research Center** *and Edgar A. Starke, Jr., of the University of Virginia. For further information, Circle 24 on the TSP Request Card.*

*This invention has been patented by NASA (U.S. Patent No. 4,820,488). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-13924.*

# Tailoring Laminates for Protection Against Projectiles

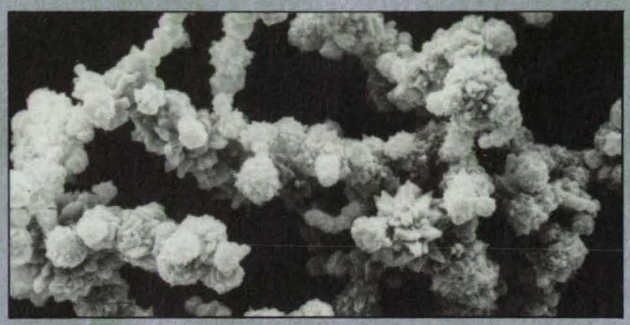
Configurations of fibers and matrices are optimized with respect to protection, bulk, and weight.

*Marshall Space Flight Center, Alabama*

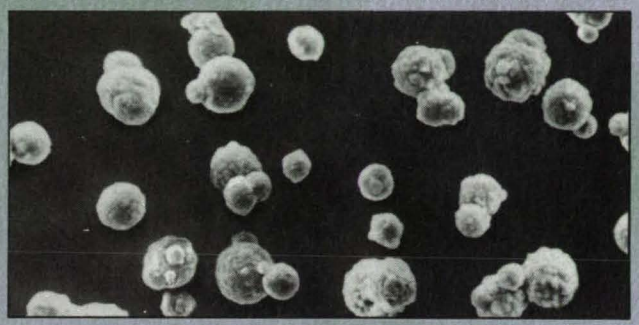
Fiber/matrix composite laminates are being developed to protect military land vehicles against projectiles and spacecraft against impacts by micrometeroids. Although the types, sizes, and velocities of the expected incident objects differ between the terrestrial and outer-space cases, the general protection problems and the solutions to them exhibit some common features: In both cases, the designer strives to select the many parameters of a fiber/matrix laminate (thickness of the whole laminate, thicknesses of sublaminates, matrix materials, fiber materials, combinations of fibers, orientations of fibers, and possibly other parameters) to obtain a shield of minimal weight and bulk that breaks a rapidly moving incident object into harmless smaller, more-slowly-moving pieces, that contains the debris, that vaporizes the debris, and/or that otherwise absorbs the kinetic energy of the object to prevent harm to the vehicle and its occupants.

The tailored-laminate concept has emerged as a synthesis of concepts that pertain to (1) thin, lightweight structural

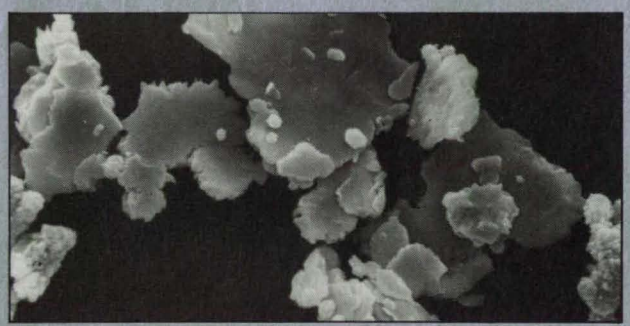
# SPECIFY INCO SPECIALTY POWDERS FOR WIDE RANGE OF ELECTRONIC APPLICATIONS



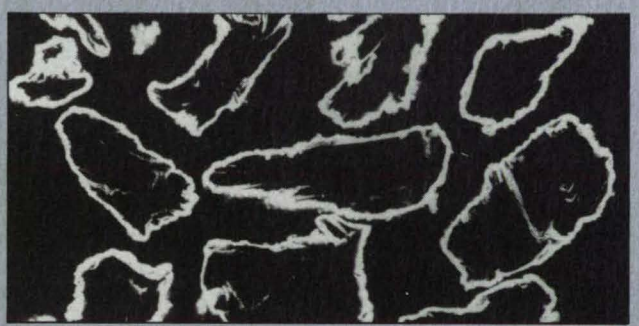
*Inco Type T 287 Filamentary Powder, particle size (FSSS) 2.6-3.3 microns, apparent density 0.75-0.95 g/cc, relative surface resistivity 0.30 ohms per square ( □ ).*



*Novamet Silver Coated Nickel Spheres, 15% Ag, 2.5 g/cc apparent density, particle size 10 microns, screen mesh 99%-250, surface resistivity 0.03 Ω/□.*



*Novamet HCA-1 Flake, screen mesh 98% minus 400, apparent density 0.90 g/cc, thickness 1.0-1.1 microns, surface resistivity 0.25 Ω/□.*



*Novamet Nickel Coated Graphite, 60% fully encapsulated Ni, apparent density 1.6 g/cc, particle size (FSSS) 100 microns, screen mesh 63% −150/+250, surface resistivity 0.3 Ω/□.*

Inco Specialty Powder Products now has a wide range of nickel and coated powders with exceptional conductive and magnetic properties. These properties make them ideal for a spectrum of electronic applications such as conducting film technology, coatings, adhesives, gaskets and EMI shielding.

## EXTENSIVE PRODUCT RANGE

The development of computer processed control coupled with the continuous powder production improvements enables us to meet your most stringent powder specifications for electronic applications.

In addition to the products pictured above, INCO SPP has available the following high performance powder products. Novamet Conductive Nickel Spheres, particle size (FSSS) 8-9 microns, apparent density 3.2-3.5 g/cc, surface resistivity 1.0 ohms per square. Novamet 525 Conductive Nickel Pigment, screen mesh 100% minus 400, particle size 3.2 microns, 0.65 BET surface area $m^2/g$, surface resistivity 0.35 ohms per square. Silver Coated Nickel Flake, 15% Ag, 2.6 g/cc apparent density, particle size (FSSS) 15 microns, screen mesh 99% minus 200, surface resistivity 0.04 ohms per square.

Magnetic ferrites and surge arrestor applications also use our specialized range of nickel oxides. High Purity Black Nickel Oxide, 77.2% Ni, BET 75 ($m^2/g$) particle size (FSSS) 5.2 microns, minus 325 mesh 99% plus. Green Nickel Oxide, 78.5% Ni, BET 3 ($m^2/g$) particle size 1.6 microns, −325 mesh 100%.

Inco Specialty Powder Products is your unique source for custom fitting high performance powders into electronic applications. Our customer focused, world-wide marketing service group is ready to help you with your current and future needs.

For more information write INCO Specialty Powder Products, Dept. 1-90, Park 80 West-Plaza Two, Saddle Brook, NJ 07662

INCO SPP

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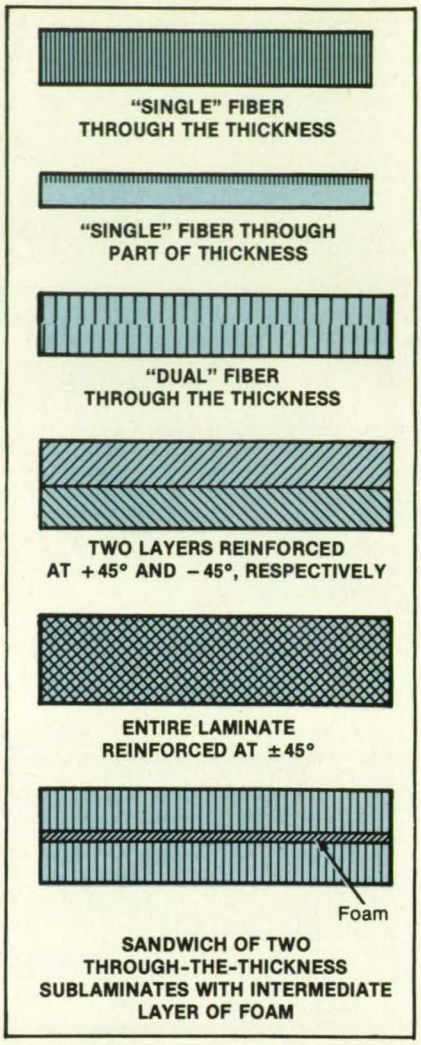
**For More Information Circle No. 652**




**Protective Laminate Panels** are tailored to specific applications by choice of the many design parameters of single or multiple layers reinforced with through-the-thickness fibers.

composites (e.g., graphite/epoxy) used in aircraft, (2) thicker ballistic laminates (e.g., glass fibers in aromatic polyamide) used as outer layers on metal armor on land vehicles, and (3) thin shields, possibly including multiple spaced layers, that have been considered for use in protecting spacecraft. One important element of this concept is that a typical protective laminate panel includes both fibers oriented conventionally in the nominal plane of the panel and fibers of the same or a different material oriented along the perpendicular and/or other out-of-plane directions. These fibers can run all or part of the way through the thickness.

The figure illustrates schematically some representative laminate panels that include through-the-thickness fibers. Typical through-the-thickness fibers could be made of boron or of tungsten coated with boron. These fibers can be incorporated into a laminate panel by use of an innovative process: The fibers are first suspended in a polymeric foam carrier that is compatible with the uncured matrix material of the laminate.

The foam is applied to the surface of the uncured laminate; then pressure is applied, causing the foam to collapse and the fibers to penetrate.

In yet another variation of the theme, a panel could also consist of multiple sublaminates that contain through-the-thickness fibers and that are separated by layers of polymeric foam. This kind of sandwich construction can be tailored to provide multiple impedances to optimize the dissipation of shock waves from impacts.

*This work was done by John J. Gassner, Joseph S. Boyce, Martin E. Smirlock, and David A. Evans of Foster-Miller, Inc., for* **Marshall Space Flight Center**. *For further information, Circle 34 on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-26153.*

# High-Performance Positive Paste for Lead/Acid Batteries

Plates covered with this paste exhibit increased porosity, strength, and energy density.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A newly formulated paste for application to the positive plates of lead/acid batteries imparts higher discharge currents and higher specific energy than does the conventional SLI paste. Other advantages of the new paste, designated F2, are that it contains no acid or free lead, no extra curing process is required, and the paste has high porosity, high surface area, and good strength.

In an SLI lead/acid battery, the energy efficiency is usually limited to less than 50 percent of the theoretical value and is even lower at a very high discharge rate. One way to obtain a high power level at a high discharge rate is to increase the porosity of the paste. However, a plate covered with the conventional SLI paste loses its strength when the porosity becomes greater than about 60 percent.

The table shows the composition of the F2 paste and compares some of its other properties with those of the SLI paste. A plate 0.05 in. (1.3 mm) thick made with the F2 paste is formed with about 20 percent surplus of theoretical capacity, as opposed to a typical 50 percent surplus of theoretical capacity for a conventional SLI plate of the same thickness. At a rate of 1 A/cm$^2$, the new plate delivers about 18 A•h/lb (40 A•h/kg), compared to about 6.3 A•h/lb (14 A•h/kg) for a conventional SLI plate.

The high porosity and surface area in the F2 paste are attributed to the large fraction of small pores with diameters less than about 500 Å. This, in turn, depends upon the presence of persulfate. If the conventional lead oxide with free lead is used instead of pure tribasic lead sulfate and orthorhombic lead oxide of the F2 mixture, high porosity and surface area cannot be achieved.

| COMPOSITION | |
|---|---|
| Proportions, Percent | Ingredients |
| 33 to 39 | Pure Tribasic Lead Sulfate ($3PbO \cdot PbSO_4 \cdot H_2O$) |
| 38 to 45 | Orthorhombic Lead Oxide (o-PbO) |
| 3.7 to 4.4 | 325-Mesh Solid Potassium Persulfate or Sodium Persulfate ($K_2S_2O_8$ or $Na_2S_2O_8$) |
| 0.08 to 0.1 | Fiber |
| The Rest | Water |

The **Composition of the F2 Paste** is shown above, while some of its characteristics are compared with those of SLI paste below.

| PROPERTIES | | |
|---|---|---|
| | F2 Paste | SLI Paste |
| Porosity | 55 to 68 Percent | 55 to 60 Percent |
| Surface Area | 4 to 7 m$^2$/g | 1 to 2 m$^2$/g |
| Formation | 135 to 165 A•h/lb | 165 to 175 A•h/lb |
| Percent Utilization | | |
| @ 3-h Discharge Rate | 45 to 68 Percent | 45 to 50 Percent |
| @ 1 A/cm$^2$ Discharge Rate | 15 to 20 Percent | Typically < 12 Percent |
| Specific Energy, A•h/lb @ 1 A/cm$^2$ Discharge Rate | 16 to 20 | 5 to 10 |

*This work was done by Wen-Hong Kao of Johnson Controls, Inc., for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 90 on the TSP Request Card.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to*

*Edward Ansell*
*Director of Patents and Licensing*
*Mail Stop 305-6*
*California Institute of Technology*
*1201 East California Boulevard*
*Pasadena, CA 91125*

*Refer to NPO-18205, volume and number of this* NASA Tech Briefs *issue, and the page number.*

# Carbon/Carbon Fasteners for Use at High Temperatures

These parts can be reused after thermal cycling.

*Lyndon B. Johnson Space Center, Houston, Texas*

Fasteners made of advanced carbon/carbon material perform well at ambient and high temperatures, tests show. The fasteners exhibited shear strengths of more than 10 kpsi (about 70 MPa) at room temperature and 13 kpsi (about 90 MPa) at a temperature of 2,700 °F (about 1,500 °C). However, the fasteners exhibited poor tensile strength — only 8 kpsi (about 55 MPa) at room temperature. The fasteners are therefore best suited to applications in which they are exposed to shear loads with minimal tension loads.

The specimens used in the tests were made from carbon/carbon stock that had been densified by chemical-vapor infiltration. Threaded specimens were machined to a 0.375-in. (9.5-mm) basic diameter at a pitch of 12 threads per in. (pitch about 2.1 mm). Pin specimens for the shear tests were made with diameters from 0.25 in. (6.35 mm) to 0.5 in. (12.7 mm). After machining, the nuts, bolts, and pins were impregnated with phenolic resin and pyrolyzed to improve their coatability. Finally, they were conversion-coated with silicon carbide. Sharp corners and edges and depressions with small radii were found to be difficult to coat. Therefore, the relatively large thread pitch was chosen to enhance coatability.

Specimens of joints were made, each

consisting of a carbon/carbon nut and bolt, a carbon/carbon spacer, and two carbon/carbon plates. Each specimen joint was tested in shear while exposed to a temperature-vs.-time profile representative of that expected to be encountered in the proposed National Aerospace Plane. After each such test, the joints could be disassembled readily. None of the components were found to have sustained any damage. The components could be resealed, reassembled into joints, and reused.

*This work was done by Frank J. Bohlmann of LTV Missiles and Electronics Group for* **Johnson Space Center**. *For further information, Circle 58 on the TSP Request Card.*
*MSC-21907*

# Carborane Dopant Strengthens Pitch Char

The carbon matrices of carbon/carbon composites can be made stiffer and stronger.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Experiments have shown that the addition of a small amount of a soluble, organic boron compound to the matrix precursor of a carbon-fiber/carbon-matrix (carbon/carbon) composite can increase the strength and toughness of the composite. The boron compound catalyzes graphitization of the matrix, giving rise to a greater degree of graphitization at a lower processing temperature. This results in a stronger, tougher composite than that made with undoped material and processed at the same temperature.

In making a carbon/carbon composite, one takes a carbonized carbon/phenolic composite and then reimpregnates it with either phenolic resin or molten pitch in order to reduce the porosity of the material. Boron has previously been used in the form of metal borides (such as $TiB_2$ or $WB_2$) as an oxidation inhibitor. This material, being insoluble, causes an increased nucleation rate, which results in a more brittle material. Processing temperature must also be limited with these materials to avoid carbide formation.

In the experimental technique, o-carborane ($B_{10}C_2H_{12}$) is added to the pitch or resin such that the quantity of boron is less than one percent atomic relative to the carbon. This is below the solid solubility limit of boron in carbon and prevents the formation of boron carbide ($B_4C$) nuclei. This technique can be used to advantage in those carbon/carbon materials requiring lower temperature processing, such as those with inhibited matrices or materials that are sensitive to changes in fiber properties.

*This work was done by D. Kyle Brown of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 81 on the TSP Request Card.*
*NPO-18214*

## Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

### Multishock Shield Against Meteoroids and Debris

Small particles are defeated by impacts on multiple, thin, shielding layers.

Two documents discuss the "multishock shielding" concept, according to which multiple spaced, very thin layers of material would protect a spacecraft against impacts by meteoroids, orbiting debris, or other projectiles traveling at hypervelocities; i.e., greater than 6 km/sec. According to this concept, the incoming projectile is broken up upon impact on the first (outermost) layer, and these fragments are then further broken up by subsequent layers. At each successive surface, the impact pressure heats the fragments, eventually melting and/or vaporizing them.

The basic problem in designing a multishock shield is to choose the number, materials, thickness, and spacings of the shielding layers to assure the complete melt and/or vaporization of a projectile before it reaches the surface to be protected. In spacecraft application, minimization of the weight of the shield is a major design consideration. The multishock shield could also do "double" or "triple" duty by providing additional thermal insulation and additional protection against ionizing radiation.

For purposes of design and experimentation, the debris particles are assumed to have a density of 2.7 g/cm$^3$ (the density of aluminum) and relative speeds of impact ranging from 2 to 16 km/sec. Meteoroids have densities of less than 1 g/cm$^3$ and an average relative impact velocity of 20 km/sec. In most of the experiments reported to date, the speeds have been about 7 km/sec. The main experimental shielding materials have been aluminum sheet in thicknesses ranging from 0.004 in. (0.1 mm) to 0.012 in. (0.3 mm) and Nextel (or equivalent), a ceramic (alumina/boria/silica) fabric of various areal mass densities from 0.028 to 0.128 g/cm$^2$.

Experiments show that the use of "very thin", as distinguished from "thin," layers is essential to the success of multishock shielding. "Very thin" in this context means that the ratio between the thickness of each layer and the original diameter of the projectile is 0.03 to 0.05, whereas in the usual thin shield, this ratio is 0.15 to 0.25. With regard to ceramic fabrics, thickness is nondescriptive; therefore, the shields are defined in terms of areal mass density.

The main differences beween the performance of the "very thin" layers of multishock shields and the "thin" typical shield bumper techniques is the repeated shocking of the projectile and its fragments to melt and/or vaporization and the small amount of destructive material produced from the "very thin" shields. As a result, the "very thin" multishock shielding layers provide more protection per unit weight. It has been estimated that the weight of a shield made of "very thin" sheets can be 20 to 30 percent less than that of a shield made of "thin" sheets.

*This work was done by Burton G. Cour-Palais and Jeanne L. Crews of* **Johnson Space Center**. *To obtain a copy of the reports, "A New Multishock Concept for Spacecraft Shielding" and "Hypervelocity Impact Shield," Circle 61 on the TSP Request Card.*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Flight Center [see page 20]. Refer to MSC-21420.*

### Effects of Irradiation by Electrons on Two Polyimides

Effects on mechanical properties expected for 30-year missions in geosynchronous orbits were studied.

The high specific strengths and stiffnesses and the low thermal-expansion coefficients of graphite-fiber-reinforced polymer-matrix composites are desired qualities for use in structures in outer space. Polyimides are among the polymers being seriously considered for future space applications because they maintain desirable mechanical properties at temperatures above 300 °C.

One polyimide currently used in outer space is a commercially available poly-

pyromellitimide. The tensile properties of films made of this polymer are relatively unaffected by ionizing radiation. However, this polymer is not available in the forms of castings and composites because of problems associated with the removal of solvents from thick cross sections during processing. Therefore, structural components cannot be made from this material.

Polyimides of a new class, known as polyetherimides, can be used for composites and castings. Polyetherimides are thermoplastics, yet they retain much of the high-temperature performance of the thermosets. However, a recent study has shown that, at least in the neat-resin form, these new polymers do not endure radiation by electrons as well as the polypyromellitimide polymer does. Therefore, a study was undertaken to compare the effects of electron radiation, in doses expected for 30-year missions in geosynchronous orbit, on the molecular structures and tensile properties of two commercially available polyimides: a polypyromellitimide and a polyetherimide.

The study included analyses of infrared (IR) and electron paramagnetic resonance (EPR) spectroscopic data for each material. The IR and EPR spectra before and after the irradiation by electrons were studied to determine the effects of the radiation doses on the molecular structures of the two materials. The spectroscopic data showed that the primary radiation-generated change in the tensile properties of the polyetherimide (a large reduction in tensile elongation) was due to cross-linking, which followed the capture, by phenyl radicals, of hydrogen atoms removed from gem-dimethyl groups. In contrast, the tensile properties of the polypyromellitimide remained unchanged because radical/radical recombination, a self-mending process, took place.

The findings of this study could be helpful in the development of new polymers that could endure radiation, in that they could lead to the synthesis of polymers that do not have methyl groups or other moieties that are sources of hydrogen, which can inhibit self-mending. The significance of this study for the polymer industry as it relates to structures in outer space could be considerable.

*This work was done by Edward R. Long, Jr., and Sheila Ann T. Long of* **Langley Research Center**. *Further information may be found in NASA TP-2663 [N87-18611], "Spectroscopic Comparison of Effects of Electron Radiation on Mechanical Properties of Two Polyimides."*

*Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.*
*LAR-14309*

## Tests of Polyurethane and Dichromate Coats on Aluminum

Equally thick coats of polyurethane or dichromate provide comparable protection against corrosion.

A report describes experiments to determine the relative effectiveness of a new polyurethane and a more-conventional dichromate coat in helping to retard the corrosion of anodized 6061-T6 aluminum. The specimens used in the experiments were anodized aluminum disks 1.43 cm in diameter and approximately 0.16 cm thick, each coated on one side with a 10.2-$\mu$m-thick layer of polyurethane or dichromate and sanded to bare metal on one side for electrical contact. Some hard-anodized specimens with dichromate coats 45.7 $\mu$m thick were also prepared. The specimens were immersed for 27 days in 3.5-percent NaCl solutions buffered at pH 5.2 and pH 9.5. A saturated calomel reference electrode was used in all measurements. Measurements of ac impedance and dc polarization resistance were made (where possible) on alternate days for the entire test period.

The parameter-vs.-time curves for the equivalent-circuit models of the ac-impedance technique generally followed expected trends. Resistances generally decreased with time, while capacitances generally increased, indicating decreases in the effective thicknesses of the protective coats represented by the dielectrics between the plates of the capacitors in the equivalent circuits.

The rates of corrosion of the specimens sealed with polyurethane and dichromate 10.2 $\mu$m thick, averaged over the first 7 days of exposure, generally compared favorably with those of the specimens sealed with dichromate 45.7 $\mu$m thick. However, rates of corrosion averaged over the entire 27-day exposure time were greater in the case of the anodized specimens with the thinner polyurethane and dichromate coats than in the case of the hard-anodized specimens with the thicker dichromate coats. It is not clear whether this effect is due to the relative thicknesses or to the fact that hard-anodizing technique is inherently more effective in protecting against corrosion.

The averages, over the 27 days, of the rates of corrosion of the specimens coated to 10.2 $\mu$m with polyurethane or dichromate were comparable. Diffusion of the surrounding medium through the polyurethane-sealed coat appeared to be somewhat slower than through the hard-anodized, dichromate-sealed coat. Contrary to the results obtained for other anodized coats, the polyurethane seal was much more effective at pH 5.2 than at pH 9.5.

The report concludes by suggesting that greater protection against corrosion might be achieved by combining the polyurethane-sealing method with the hard-anodizing method and by increasing the thickness of the coat.

*This work was done by M. D. Danford of* **Marshall Space Flight Center**. *Further information may be found in NASA TM-100394 [N90-21191], "The Corrosion Protection of 6061-T6 Aluminum by a Polyurethane-Sealed Anodized Coat."*

*Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.*
*MFS-27249*

## Alloys for Flexible Hoses in a Corrosive Environment

A high-nickel alloy resists pitting corrosion.

A report evaluates metal alloys for flexible hoses in a corrosive environment. The alloys were tested to find alternatives to the 304L stainless steel used in convoluted flexible expansion joints in vacuum-jacketed tubes that contain cryogenic liquids at the Space Shuttle launch site. The joints are exposed to a salty seaside atmosphere and to hydrochloric acid in solid rocket combustion products. In this environment, many joints have developed pitting corrosion and consequent pinhole leaks.

Nineteen alloys were selected for testing on the basis of their reputation for resistance to corrosion. They were subjected to the following tests:

- Electrochemical corrosion;
- Accelerated corrosion with exposure in a salt-fog chamber and dipping in a solution of hydrochloric acid with alumina particles stirred in;
- Long-term exposure at the KSC Beach Corrosion Test Site and spraying with a slurry of alumina particles in hydrochloric acid; and
- Pitting corrosion in ferric chloride solution.

The top five alloys, in order of decreasing resistance to corrosion, were found to be Hastelloy** C-22, Inconel* 625, Hastelloy** C-276, Hastelloy** C-4, and Inco* alloy G-3. Of these, Hastelloy** C-22 was found to be the best for the flexible-hose application.

**"Hastelloy" is a registered tradmark of Haynes International.

*"Inconel" and "Inco" are registered trademarks of the Inco family of companies.

*This work was done by Louis G. MacDowell, III, and Cordelia Ontiveros of* **Kennedy Space Center**. *To obtain a copy of the report, "Evaluation of Candidate Alloys for the Construction of Metal Flex Hoses in the STS Launch Environment," Circle 98 on the TSP Request Card.*
*KSC-11480*

# Computer Programs

**COSMIC: Transferring NASA Software**

COSMIC, NASA's Computer Software Management and Information Center, distributes software developed with NASA funding to industry, other government agencies and academia.

COSMIC's inventory is updated regularly; new programs are reported in *Tech Briefs*. For additional information on any of the programs described here, circle the appropriate TSP number.

If you don't find a program in this issue that meets your needs, call COSMIC directly for a free review of programs in your area of interest. You can also purchase the annual *COSMIC Software Catalog,* containing descriptions and ordering information for available software.

COSMIC is part of NASA's Technology Transfer Network.

COSMIC®— *John A. Gibson, Director,*
Phone (706) 542-3265 ; FAX (706) 542-4807
The University of Georgia, 382 East Broad Street, Athens, Georgia 30602

## Computer Programs

These programs may be obtained at a very reasonable cost from COSMIC, a facility sponsored by NASA to make computer programs available to the public. For information on program price, size, and availability, circle the reference number on the TSP Request Card in this issue.

## Machinery

### Computing Thermodynamics of Cryostorage Tanks in Orbit

No-vent filling, boiloff, and other phenomena can be predicted.

The Cryogenic On-Orbit Liquid Analytical Tool (COOLANT) computer program has been developed to analyze the thermodynamic processes required in maintaining and utilizing a cryogen depot tank in a microgravity environment. The code contains four major analysis modules, a tank-geometry module, and a data base of properties of fluids and other materials. COOLANT is modular, so that its algorithms and data bases can be upgraded and expanded as required.

The No-Vent Fill analysis module computes aspects of the chilldown and nonvented filling of a receiver tank. The analytical predictions include the following: the mass of a cryogen needed to chill a warm tank, the time required to perform the chill and fill, and the pressure history of the receiver tank during the filling process. This module performs a quasi-steady-state analysis to model the prechill and fill phases of the transfer of fluid in low gravity.

Prechill is analyzed in a series of "charge/hold/vent" cycles. The tank to be filled is charged with a specified quantity of liquid by injection from spray bars mounted in the tank, then some time is allowed to pass while the fluid exchanges heat with the cold mass of the tank, and then the tank is vented to low pressure. This cycle is repeated until the specified low temperature is reached.

The chilled and evacuated tank is then locked up and liquid is injected into the tank by spray bars to fill the tank without venting. COOLANT enables the user to perform tradeoff studies on the efficiency of the chilldown process versus the time required to achieve chilldown. The user can also determine the droplet-to-bubble-dominated modes of exchange of energy during the fill process.

Losses caused by boiloff during long-term storage are predicted by the System Performance module. This module provides for (1) parametric studies of a variety of thermal-control systems and insulations including foam, multilayered insulation, vapor-cooled shields, and combinations thereof and (2) the coupling of a shield that is mounted on the outside of a liquid-oxygen tank and that is cooled by hydrogen vapor. The System Performance module can read heat-rate-versus-time data from the output file of the Thermal Radiation Analysis System (TRASYS: COSMIC inventory number MSC-21030) program. This module mathematically models the rise and decay of pressure in a tank that is (1) under a low or zero local acceleration (contents of tank in equilibrium) and (2) equipped with a thermodynamic vent system that reduces the pressure in the tank by removing both mass and heat.

The Tank Outflow module analyzes the thermodynamics of tanks during pump-assisted or pressure-fed transfer of fluid from one tank to another. This module calculates pressurant requirements for specified transfer parameters. The times required for expulsion from, and reequilibration of, a supply tank and the transfer losses are calculated by modeling the thermodynamics of an autogenous pressurization system.

In addition to the on-orbit analyses modules, the program contains the Settled Fill module, which is for the study of loading propellants under normal Earth gravitation. This module models the vented chilldown and fill of a cryogenic tank under such settled conditions as the ground loading of cryogens into a launch vehicle.

The Tank Geometry module supports the analysis modules by calculating various geometric parameters of spherical tanks and cylindrical tanks with spherical or elliptical end caps.

COOLANT includes a fluid-properties data base that contains information on the thermodynamic and transport properties of helium, hydrogen, nitrogen, oxygen, Freon-113 (trichlorotrifluoroethane), and Freon-114 (dichlorotetrafluoroethane), and data on other fluids can be added. The data base on other materials contains specific heats and thermal conductivities of 5 aluminum alloys, 10 stainless-steel alloys, 2 phenolic carbon wraps, fiberglass, silver, copper, magnesium, beryllium copper, gold, Inconel, and titanium. Several component-performance modules, used to model storage-system penetrations and subsystems, can be selected as options.

The COOLANT program is written in FORTRAN 77 for DEC VAX-series computers running VMS. COOLANT is configured to use the Tektronix PLOT10 package for plotting outputs; however, the program can be compiled and linked without the plot library. The outputs of the mathematical models in COOLANT can be represented in file format or graphically, characterized by the histories of quantified (boiloff, pressure, rates of flow, and the like) variables. This software requires approximately 365K of main memory. COOLANT is available on a 9-track, 1,600-bit/in. (630-bit/cm) DEC VAX BACKUP format magnetic tape (standard distribution medium) or on a TK50 tape cartridge. This version of COOLANT was developed in 1989.

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*This program was written by N. Brown, S. Tucker, and M. Liggett of General Dynamics for* **Marshall Space Flight Center**. *For further information, Circle 63 on the TSP Request Card.*
*MFS-28583*

## Mathematics and Information Sciences

### C Language Integrated Production System, Version 5.0

CLIPS 5.0 includes enhancements of rule-based, object-oriented, and procedural programming.

CLIPS, the C Language Integrated Production System, is a computer program that provides a complete environment for the development of expert-system soft-

ware — programs that are specifically intended to model human expertise or knowledge. CLIPS is designed to enable research on, and the development and delivery of, artificial intelligence on conventional computers. CLIPS 5.0 provides a cohesive software tool for handling a wide variety of knowledge with support for three different programming paradigms: rule-based, object-oriented, and procedural. CLIPS 5.0 is available in a version for the IBM Personal Computer (MSC-21916), in one for the Macintosh computer (MSC-21927), and in one for the DEC VAX computer (MSC-21929).

Rule-based programming allows the representation of knowledge by use of heuristics, or "rules-of-thumb," which specify sets of actions to be performed in given situations. This was the primary paradigm of programming supported by prior versions of CLIPS. Object-oriented programming allows the modeling of complex systems as modular components (which can be easily reused to model other systems or create new components). The procedural programming capabilities provided by CLIPS 5.0 enable CLIPS to represent knowledge in ways similar to those allowed in such languages as C, Pascal, Ada, and LISP. Working with CLIPS 5.0, one can develop expert-system software by use of rule-based programming only, object-oriented programming only, procedural programming only, or combinations of the three.

Originally, the primary method of representation in CLIPS was a forward-chaining-rule language based on the Rete algorithm. The term Production System in the CLIPS acronym alludes to this rule-based paradigm of programming. It includes three basic elements: a fact list containing data that represent the current state of the "world," a knowledge base of "if–then" rules, and an inference engine. The "if" portion of a rule is a series of patterns (conditions) that specify the facts (data) that cause the rule to be applicable. The "then" portion of a rule is the set of actions to be executed when the rule is applicable. The rules are called productions, and the collection of conditions and actions to be taken if the conditions are met is constructed into a rule network. The inference engine matches patterns against facts using the Rete algorithm and determines which rules should be executed and when.

Version 5.0 of CLIPS includes extensive enhancements of this rule-based paradigm of programming. A feature called "Incremental Reset" allows rules to "see" facts that are entered before or after the rules. Seven strategies for conflict resolution are supported. These strategies are called "Depth," "Breadth," "LEX" (lexicographic), "MEA" (means–end analysis), "Complexity," "Simplicity," and "Random." There is also a feature to maintain truth by internally tagging those facts that are logically dependent on others: If certain facts are retracted, CLIPS will automatically retract the logically dependent facts.

Object-oriented programming (OOP) combines aspects of both data-abstraction and procedural knowledge. This paradigm of programming allows data and procedures to be closely coupled within objects — the procedures for manipulating the data pertaining to an object are considered to be part of the object. The CLIPS object-oriented language, COOL, is a hybrid of features from many different OOP systems as well as new ideas. Features supported by COOL include classes with multiple inheritance, abstraction, encapsulation, polymorphism, dynamic binding, and message-passing with message-handlers. The first five features in this list are the five primary features that an OOP system must possess.

Prior to version 5.0, the only procedural programming supported by CLIPS was the definition, by the user, of external functions. These functions, which are still supported, are defined in an external language, such as C, and are called from within CLIPS. Before functions of this type can be called from within CLIPS, however, CLIPS has to be recompiled and relinked with them. In contrast, a new procedural programming capability of CLIPS 5.0 enables programmers to define new functions within CLIPS without having to recompile and relink CLIPS. These functions are known as "deffunctions". Generic functions are similar to deffunctions in that they can be used to define new procedural code directly in CLIPS, and they can be called like any other function. However, generic functions are much more powerful because they can be overloaded in a manner similar to that of operator overloading in such languages as Ada and C++. COOL also overlaps procedural programming to a certain degree because message-handlers are pieces of procedural code that implement specified behaviors for particular classes of objects in response to particular messages.

Like version 4.3, CLIPS 5.0 includes an integrated MicroEMACS editor and an online help facility. Both integer and double-precision types of data are supported, and global variables can be defined and used. CLIPS 5.0 also provides a "constructs-to-c" function, which can be used to create multiple run-time modules (each of which includes the user's choice of rules and other constructs). Switching between different images created by use of the constructs-to-c function is also supported. The CRSV (Cross-Reference, Style, and Verification) utility is still available to aid in development, debugging, and verification of large rule bases; however, it has not been extended to support all new features of CLIPS 5.0.

COSMIC offers five distribution versions of CLIPS 5.0. Executable files, source code, utilities, and examples are included on the

program medium. All distribution versions include identical source code for the command-line version of CLIPS 5.0. This source code is compatible with ANSI C and should be compilable on any computer with an ANSI C compiler. Only the Macintosh version of CLIPS 5.0 includes a window interface.

The executable code provided with the PC version (MSC-21916) was built with Borland's ANSI C compiler with VROOM overlays (included in their version 1.01 of the Turbo C++ and version 2.0 of the Borland C++ v2.0 software products) to enable the inclusion of all the program features and still allow enough memory to build application programs within 640K of memory. Because of the overlays, the executable code of this version runs very slowly on 808x- and 80286-based computers without expanded or extended memories, but an executable code built without overlays does not run at all on such computers unless compiler flags are set to deactivate one or more of the features of CLIPS (e.g., rules, COOL, deftemplates, deffunctions, the editor, the help system). Large application programs require an 80286 or better central processing unit, a DOS extender, and a CLIPS executable code that has been recompiled by use of the facilities of the DOS extender. "Makefiles" for recompiling the source code on UNIX machines are included with the PC version.

The version of CLIPS 5.0 for IBM PC-compatible computers (MSC-21916) requires DOS v2.11 or later, and is distributed in compressed form on four 5.25-in. (13.34-cm), 360K, MS-DOS-format diskettes. A hard disk is required. The Macintosh version (MSC-21927) is distributed in compressed form on two 3.5-in. (8.9-cm), 800K, Macintosh-format diskettes, and requires System 6.0.5 and 1 Mb of random-access memory. The version for DEC VAX/VMS (MSC-21929) is available in VAX BACKUP format on either a 1,600-bit/in. (630-bit/cm) 9-track magnetic tape (standard distribution medium) or a TK50 tape cartridge. The DEC RISC ULTRIX version is distributed on a TK50 tape cartridge in UNIX tar format. A UNIX version, which includes binaries for Sun-3 and Sun-4 computers, is available on a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format.

The documentation of CLIPS 5.0 includes a three-volume reference manual (Basic and Advanced Programming Guides, and Utilities & Interfaces Guide), and a two-volume user's guide (Rules and Objects). CLIPS was developed in 1986, and Version 5.0 was released in 1991.

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*This program was written by Gary Riley, Brian Donnell, Huyen-Anh Vu Ly, Chris Culbert, and Robert T. Savely of* **Johnson Space Center**; *Joseph Giarratano of Barrios Technology; and Stephen Baudendistel, Andrew Cunningham, and Cynthia Rathjen of Computer Sciences Corp.*

*For further information, Circle 106 on the TSP Request Card.*
*MSC-21929, MSC-21916, and MSC-21927*



## Efficient Two-Dimensional-FFT Program

This program computes a 64×64-point fast Fourier transform in less than 17 ms.

Scientists at Goddard Space Flight Center have developed an efficient and powerful program — An Optimized 64×64 Point Two-Dimensional Fast Fourier Transform — that combines the performance of real- and complex-valued one-dimensional fast Fourier transforms (FFT's) to execute a two-dimensional FFT and the coefficients of its power spectrum. These coefficients can be used in many applications, including analyzing spectra, convolution, digital filtering, processing images, and compressing data.

The efficiency of the program results from its technique of expanding all arithmetic operations within one 64-point FFT; its high processing rate results from its operation on a high-speed digital signal processor. For non-real-time analysis, the program requires as input an ASCII data file of 64×64 (4,096) real-valued data points. The output of the program is an ASCII data file of 64×64 power-spectrum coefficients.

To generate these coefficients, the program employs a row-column decomposition technique. First, it performs a radix-4 one-dimensional FFT on each row of input, producing complex-valued results. Then, it performs a one-dimensional FFT on each column of these results to produce complex-valued two-dimensional FFT results. Finally, the program sums the squares of the real and imaginary values to generate the power-spectrum coefficients.

The program requires a Banshee accelerator board with 128K bytes of memory from Atlanta Signal Processors installed on an IBM PC/AT-compatible computer (DOS ver. 3.0 or higher) with at least one 16-bit expansion slot. For real-time opera-

tion, an ASPI daughter board is also needed. The real-time configuration reads 16-bit integer input data directly into the accelerator board, operating on 64×64 point frames of data. The memory-management portion of the program also provides for accumulation of the computed coefficients. The time required to calculate and accumulate the 64×64 power-spectrum output coefficients is less than 17.0 ms.

Documentation is included in the price of the program. Source code is written in C, 8086 Assembly, and Texas Instruments TMS320C30 Assembly languages.

IBM and IBM PC are registered trademarks of International Business Machines.

*This program was written by J. Miko of* **Goddard Space Flight Center**. *For further information, Circle 32 on the TSP Request Card.*
*GSC-13340*

## Life Sciences

### Software for Genetic Algorithms

SPLICER provides software support for building search and optimizing programs.

The SPLICER computer program is a genetic-algorithm software tool that can be used to solve search and optimization problems. [Genetic algorithms effect adaptive search procedures (i.e., problem-solving methods) based loosely on the processes of natural selection and Darwinian "survival of the fittest."]

SPLICER provides the underlying framework and structure for building a genetic-algorithm application program. Genetic algorithms apply genetically inspired operators to populations of potential solutions in an iterative fashion, creating new populations while searching for an optimal or near-optimal solution to the problem at hand.

SPLICER 1.0 was created by use of a modular architecture that includes a genetic-algorithm kernel, interchangeable representation libraries, fitness modules, and user interface libraries, plus well-defined interfaces between these components. The architecture supports portability, flexibility, and extensibility. SPLICER comes with all source code and several examples. For instance, a "traveling salesperson" example searches for the minimum distance through a number of cities, visiting each city only once. Stand-alone SPLICER application programs can be used without any programming knowledge. However, to fully utilize SPLICER within new problem domains, familiarity with C-language programming is essential.

The genetic-algorithm (GA) kernel in SPLICER was developed to be independent of representation (i.e., problem encoding), fitness function, or user interface type. The GA kernel comprises all functions necessary for the manipulation of populations. These functions include the creation of populations and population members, the iterative population model, fitness scaling, parent selection and sampling, and the generation of population statistics. In addition, miscellaneous functions are included in the kernel (e.g., random-number generators).

Various problem-encoding schemes and functions are defined and stored in interchangeable representation libraries. This enables the GA kernel to be used with any representation scheme. The SPLICER tool provides representation libraries for binary strings and for permutations. These libraries contain functions for the definition, creation, and decoding of genetic strings, as well as multiple crossover and mutation operators. Furthermore, the SPLICER software tool defines the appropriate interfaces to enable users to create new representation libraries.

Fitness modules are the only components of the SPLICER system a user will normally need to create or alter to solve a particular problem. Fitness functions are defined and stored in interchangeable fitness modules, which must be created by use of C language. Within a fitness module, a user can create a fitness (or scoring) function, set the initial values of various SPLICER control parameters (e.g., size of population), create a function that graphically displays the best solutions as they are found, and provide descriptive information about the problem. SPLICER includes several example fitness modules, while the process of developing a fitness module is fully discussed in the accompanying documentation. The user interface is event-driven and provides graphic output in windows.

SPLICER is written in Think C for Apple Macintosh computers running System 6.0.3 or later. Examples of executable and source codes are included in the software package. The standard distribution medium is three 3.5-in. (8.89-cm) Macintosh-format diskettes. An electronic copy of the documentation is included on the program medium. SPLICER was developed in 1991.

Apple Macintosh is a registered trademark of Apple Computer, Inc. THINK C is a trademark of Symantec Corp. X Windows is a trademark of Massachusetts Institute of Technology.

*This program was written by Lui Wang of* **Johnson Space Center** *and Steve E. Bayer of the Mitre Corp. For further information, Circle 85 on the TSP Request Card.*
*MSC-21904*

# Robotic Gripper Resists Torsion and Lateral Forces

Gripping surfaces are contoured to prevent lateral forces from prying them apart.

*Goddard Space Flight Center, Greenbelt, Maryland*

A gripper for the end effector of a robot is shaped so that it tolerates large initial misalignments with an object to be gripped, but most forces on the object do not tend to pry the gripper away, once the grip has been established.

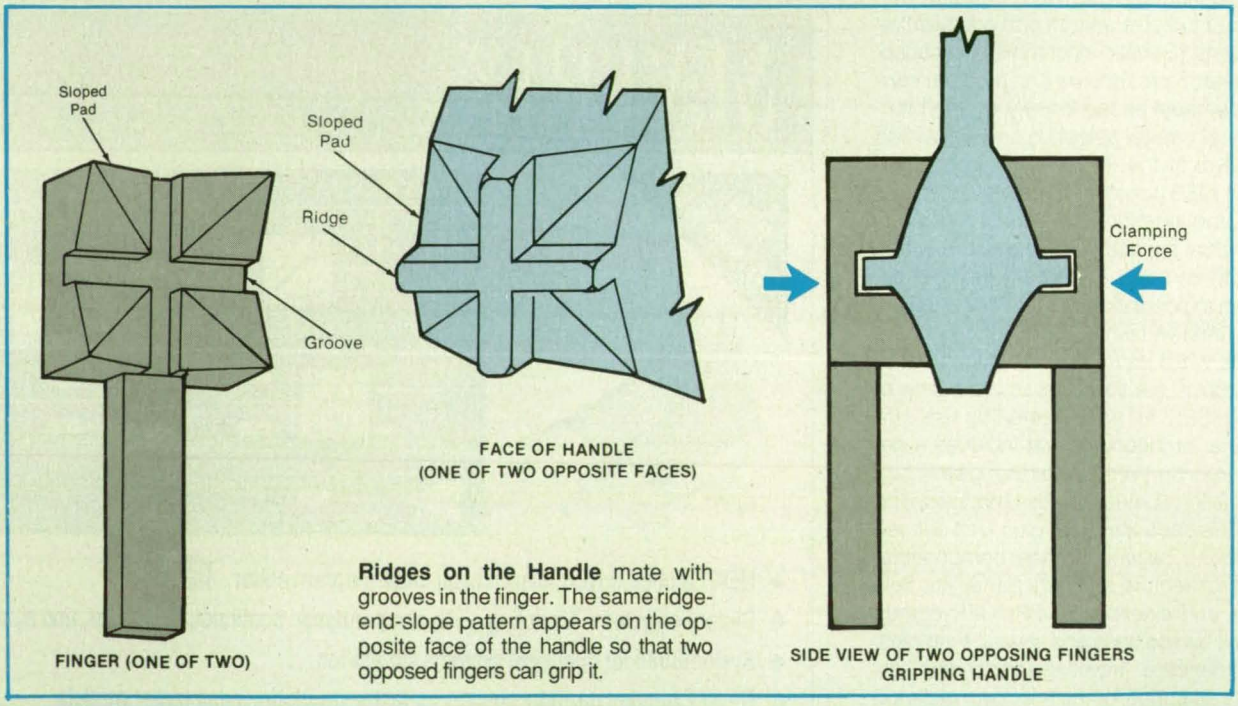
The gripper consists of a pair of opposing fingers that grasp a mating handle on the object. On each finger (see figure), two orthogonal grooves constitute a cruciform recess, and outwardly pointed pads form orthogonal notches with V-shaped cross sections. The contours of the handle are the negative of those of the finger; four inwardly pointed pads on each of two opposing faces of the handle are capped by a protruding cruciform ridge.

As the fingers close on the handle, the ridges on the handle make contact with the sloped finger pads. This sets up forces that are sensed by force and/or torque sensors in the wrist of the robot. The force and/or torque feedback is used by a teleoperator (if the robot is controlled manually) or by an electronic control system (in the case of an autonomous robot) to guide the fingers into alignment with the handle.

When the fingers and handle are properly aligned, the ridges on the handle mesh with the grooves in the fingers, and the grip is established. The ridges fit loosely in the grooves, so that when the fingers and handle are aligned perfectly and there is some clamping force, contact is between the sloped faces of the fingers and those of the handle. Ordinarily, in this condition, twisting the handle or pushing it sideways in the fingers would tend to force the fingers apart, with the sloped surfaces acting as ramps. However, the cruciform ridges and grooves prevent this; twisting the handle or pushing it sideways forces the ridges into contact with the walls of the grooves, and the orientation of this contact is such that there is no component of force pushing the fingers apart, only a force pushing them sideways. Therefore, in designing the mechanism that drives the robotic gripper, one does not have to take account of gripper-opening forces caused by torques about, or forces perpendicular to, the common axis through the centers of the cruciform ridges and grooves.

*This work was done by George M. Voellmar of* **Goddard Space Flight Center**. *For further information, Circle 21 on the TSP Request Card.*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 20]. Refer to GSC-13356.*




**Ridges on the Handle** mate with grooves in the finger. The same ridge-end-slope pattern appears on the opposite face of the handle so that two opposed fingers can grip it.

# Preliminary Design of Adhesively Bonded Composite Joints

Joints should be symmetrical and long enough to withstand cyclic loads and hygrothermal effects.

*Lewis Research Center, Cleveland, Ohio*

A step-by-step procedure for the preliminary design of adhesively bonded joints between laminated fiber-reinforced-matrix composite bars is based on simplified methods for the prediction of microstresses and local strengths, including interlaminar strengths. The procedure involves approximate calculations of the stresses in the various components of a joint. It includes calculations

to determine such critical parameters as the minimum length, the maximum shear stress in the adhesive, and the peeloff stress. The deleterious effects of cyclic loading, increased temperature, and humidity are also taken into account.

The steps of the procedure are the following:

1. Establish the design requirements, including loads, laminates, adhesive, and safety factors.
2. By use of the theory of the mechanics of composites, obtain the dimensions and properties for the adherends.
3. Obtain the shear and peeloff strengths of the adhesive, which, in many cases, will be the same as the matrix material in the adherends.
4. Compute the degradation of the shear and peeloff strengths by moisture, temperature, and cyclic loads, by use of the following equation:

$$\frac{S_a}{S_{ao}} = \left(\frac{T_{gw} - T}{T_{gd} - T_o}\right)^{1/2} - 0.1 \log N$$

where $S_a$ is the expected adhesive strength being calculated for a particular loading environment; $S_{ao}$ is the corresponding strength at reference conditions, usually taken as room-temperature dry; and $T$ is the temperature of the loading environment. $T_{gw}$ is the glass-transition temperature of the adhesive when it is wet, given by

$$T_{gw} = (0.005M^2 - 0.1M + 1.0)T_{gd}$$

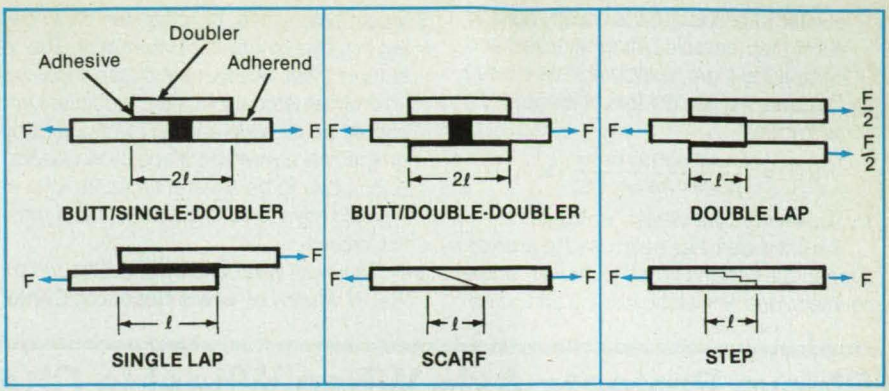
where $M$ is the moisture in the adhesive in percent by weight and $T_{gd}$ is the glass-transition temperature of the adhesive when it is dry, usually specified by the supplier. $T_o$ is the reference temperature at which $S_{ao}$ was determined, usually taken as room temperature. $N$ is the number of cycles the joint must endure under the design stress.

5. If the design allowables have not already been set pursuant to the design criteria, set them according to either a safety factor (usually 1.5 or 2) for the applied force or else a safety factor of half the degraded adhesive strength $S_a$ calculated in step 4. Inasmuch as the design force may already include a safety factor, the second alternative is preferable.
6. Select the length, $l$, of the joint by using the following equation:

$$l = \frac{F}{S_{as}}$$

where $F$ denotes the load (tensile/compressive/shear) per unit width in the adherends and $S_{as}$ denotes the design-allowable shear stress in the adhesive.

7. Calculate the minimum length and the maximum shear and normal stresses in the adhesive.
8. Calculate the bending stresses in the doublers and adherends.
9. Calculate the margin of safety for all cal-




These are **Common Types of Adhesively Bonded Joints** between laminated composite bars.

culated stresses. (This is usually done at each step by calculating stresses and comparing them to allowable stresses.)

10. Calculate the percent joint efficiency (*J.E.*) as follows:

$$J.E. = \frac{\text{Joint force } (F) \text{ transferred}}{\text{Adherend fracture load}} \times 100$$

11. Summarize the design of the joint.

The procedure has been used to analyze two sample designs of butt joints with single doublers: one with static loading and no environmental effects, the other with cyclic loading in a hygrothermal environment. The results of these two sample cases show that (1) unsymmetrical joints are inefficient and should be avoided and (2) to endure a hygrothermal environment and cyclic loading, a joint has to be several times as long as it would have to be in the absence of these conditions.

*This work was done by C. C. Chamis and P. L. N. Murthy of* **Lewis Research Center.** *Further information may be found in NASA TM-102120 [N89-26048], "Simplified Procedures for Designing Adhesively Bonded Composite Joints."*

*Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.*

*LEW-15050*

# Sleeve Protects Axle When Wheel Is Changed

The sleeve covers the plated outer surface to prevent wear.

*John F. Kennedy Space Center, Florida*

A sleeve protects a chromium-plated surface near the outer end of an axle from scratches during wheel changes. The sleeve is designed to fit the axle on the nose landing gear on the Space Shuttle, but the underlying sleeve concept is applicable to commercial and military aircraft and ground vehicles as well.

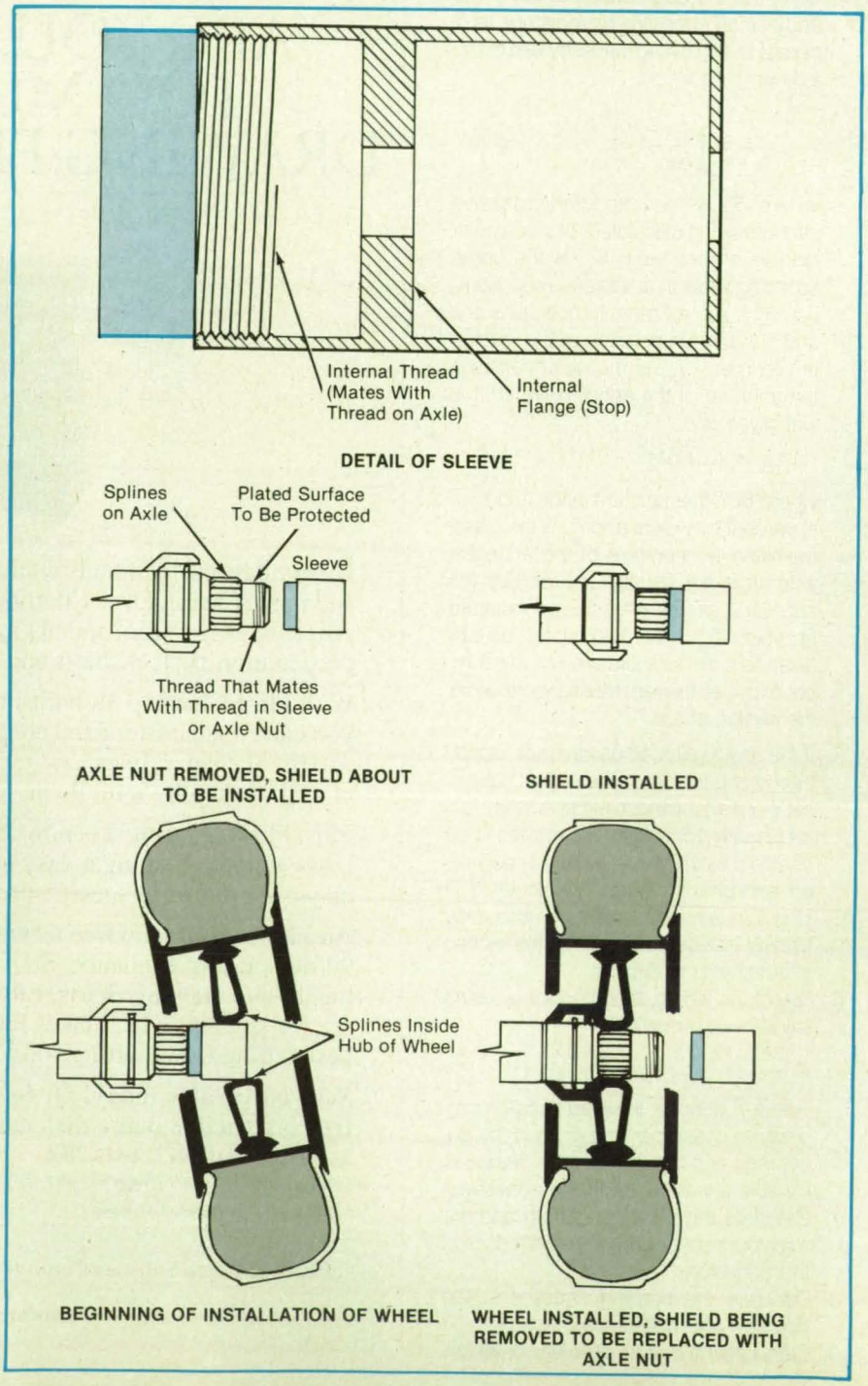
The sleeve is installed on the outer end of the axle after the axle nut is removed but before the wheel is replaced. It is attached by use of the same thread that engages the axle nut during operation. It shields the plated surface from contact with splines inside the hub of the wheel that mate with splines on the axle (see figure). The sleeve thereby prevents scraping and flaking of the chromium plate as the wheel is slid onto or off the axle. The sleeve is removed when installation is complete.

The sleeve is machined from a cylindrical bar of an aluminum/nickel alloy. An internal thread near the open end of the sleeve engages the thread on the end of the axle that normally engages the axle nut. A polytetrafluoroethylene extension is adhesively bonded to a recess at the inner end of the sleeve.

When the sleeve is slipped onto the axle, the polytetrafluoroethylene extension covers the chromium-plated surface to be protected. A wide flange inside the sleeve prevents overtightening when the sleeve is screwed onto the axle. A hole in the flange vents trapped air and gives the technician a view of the approach of the flange to the end of the axle.

*This work was done by Mark R. Bupp of Rockwell International Corp. for* **Kennedy Space Center.** *For further information, Circle 26 on the TSP Request Card.*

*KSC-11434*




The **Cross Section of the Protective Sleeve** shows the internal flange, which serves as a stop to prevent overtightening. The installation sequence shows how the sleeve shields the axle from abrasion by splines in the hub of the wheel.

# Fixed or Controlled-Movement Foot Restraint

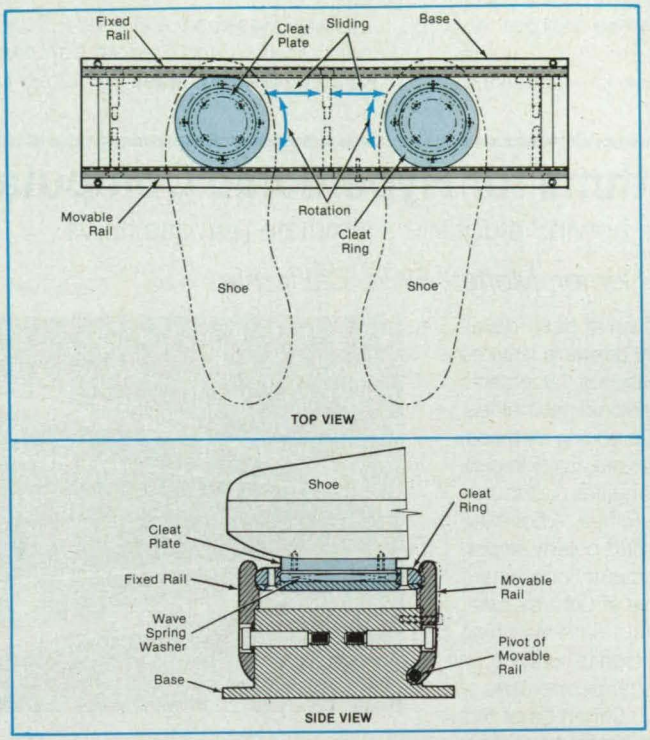
Ingress, egress, rotation, and translation are all accomplished with ease.

*Lyndon B. Johnson Space Center, Houston, Texas*

A foot restraint gives a user three options: it holds the user's feet in a fixed position, allows them to slide sideways, or allows them to pivot independently about an axis through the ball of the foot, as the user chooses. The user can therefore select the degree of restraint to suit the task at hand — fixed for precise, difficult tasks or sliding or rotating when tasks have to be performed at different locations or when parts or tools have to be selected at adjacent areas. Designed for use in the absence of gravitation, the restraint may be useful on Earth underwater or in some hazardous locations where movements must be restricted.

The restraint consists of a pair of cleats — one on each of the user's shoes — a two-rail track into which the cleats fit, and a base that supports the track (see figure). To enter the restraint, the user places one foot at a time on the track so that the disklike cleats force the movable member of the track pair slightly outward. When the edge of each cleat engages a groove in each rail, a spring forces the movable rail back to its inner position, and the user's foot is secured in the restraint.

To move a foot along the track, the user simply moves the leg so that the cleat slides in the grooves in the rails. To rotate a foot, the user pushes downward with the foot, compressing a wave spring washer and disengaging ribs in the cleat plate and ring from each other. The user can then pivot the foot to a new angular position and release the downward force on the foot. The wave spring washer pushes the cleat plate upward, reengaging the ribs in the cleat plate and ring so that the restraint is once again locked against rotation. To remove a foot from the restraint, the user pulls the leg upward, forcing the movable rail outward and extracting the edges of the cleat from the grooves in the rails.




**Movements To Enter and Leave the Foot Restraint** are simple and direct. The user simply forces each cleat lightly into the space between the rails until the spring force of the movable rail secures it. Body movements for sliding and rotation are equally straightforward.

*This work was done by Gloria B. Reilly and Noah Blizzard of Johnson Engineering Corp. for* **Johnson Space Center**. *For further information, Circle 59 on the TSP Request Card.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to*

*Noah Blizzard*
*Johnson Engineering Corp.*
*1620 Bay Ave. Blvd. No. 904*
*Houston, TX 77058*

*Refer to MSC-21438, volume and number of this* NASA Tech Briefs *issue, and the page number.*

# Contraction-Only Exercise Machine

Muscles are relieved of load during extension.

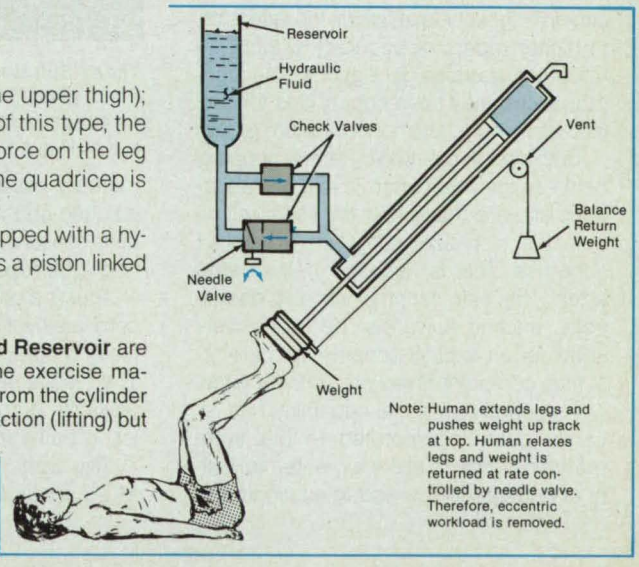
*John F. Kennedy Space Center, Florida*

A modified exercise machine loads the affected muscles during contraction — i.e., extension of legs — only. The machine was developed for experiments to test the thesis — held by some muscle physiologists — that concentric exercise may be more or less effective than concentric/eccentric exercise; i.e., lift and lower weight. If it is more effective, then exercise could be made more efficient and less time-consuming by use of an exercise machine that applies the more-effective loads or combinations of loads.

A standard knee-extension machine was modified so that the subject experiences a force only when lifting a leg against a stack of weights (contracting the quadricep, the large muscle in the upper thigh); unlike ordinary machines of this type, the modified unit exerts little force on the leg while it is being lowered (the quadricep is being extended).

The modified unit is equipped with a hydraulic cylinder that contains a piston linked

The **Hydraulic Cylinder and Reservoir** are mounted on the frame of the exercise machine. The fluid flows freely from the cylinder to the reservoir during contraction (lifting) but in constricted fashion from the reservoir to the cylinder during extension (lowering).



to a stack of weights. One of two check valves remains open while the leg is moving upward against the weights so that hydraulic fluid flows freely from the reservoir into a cylinder. When the leg reaches its highest position and starts to come down, the first check valve closes. The cylinder then pushes fluid out through a needle valve that resists the flow to a degree that has been adjusted to accommodate the weight and frequency of the exercise regimen. The hydraulic cylinder, instead of the leg, then supports the stack of weights as it slides down gently to the starting position.

*This work was done by Donald F. Doerr, Arthur B. Maples, and Craig M. Campbell of* **Kennedy Space Center**. *For further information, Circle 103 on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center* *[see page 20].* *Refer to KSC-11513.*

# Two Algorithms for Hypersonic Computations

Strongly coupled, upwind algorithms simulate real gas flows.

*Ames Research Center, Moffett Field, California*

Two new algorithms have been developed that contain several desirable features for the computation of viscous, hypersonic flows about three-dimensional geometries. Both employ upwind-differencing methods, which have the unsurpassed ability to capture flow-field discontinuities without a need for any user-specified smoothing terms. This feature is particularly important in hypersonic computations where many complicated wave structures exist.

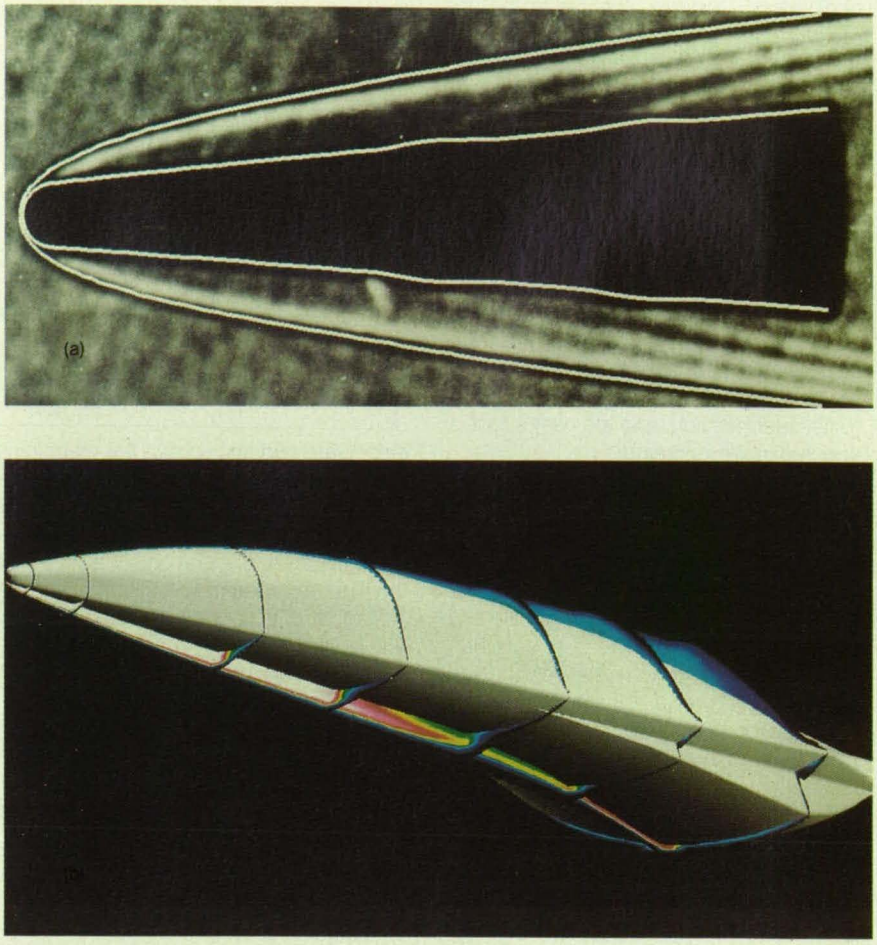
The first algorithm is a time-marching scheme. It is generally used to obtain solutions in subsonic or separated regions of a hypersonic flow field. Schemes of this nature can require long computing times, making it impractical to compute an entire hypersonic flow field with reasonable resolution. Therefore, a second, less expensive algorithm was developed for the computation of the larger, supersonic portion of the flow field. This second algorithm is a parabolized Navier–Stokes, space-marching scheme that obtains a solution in relatively little computer time.

Both algorithms are based on a finite-volume formulation to ensure that the schemes, including the boundary conditions, are fully conservative. Further they obtain their upwind inviscid fluxes by employing a new temporal Riemann solver. The implementation of a total-variation-diminishing technique allows the extension to higher orders of accuracy without introducing spurious oscillations. The algorithms currently have capabilities for perfect, equilibrium, and nonequilibrium gases.

Both algorithms employ strong coupling between the fluid-dynamic and gas equations and are made fully implicit to eliminate the step-size restriction of explicit schemes. This is necessary since step sizes in the calculation of viscous, chemically reacting flows can be excessively small for an explicit scheme, and the resulting computer times prohibitively large.

A generalized, zonal capability has recently been incorporated in the time-marching code to allow a greater flexibility of grid generation and to eliminate the memory limitations of large problems. A patched-grid method is used that maintains conservation and allows a wide variety of grid topologies.

These algorithms have been used to compute hypersonic flows about both simple and complex geometries (see figure). The results of these computations agree well with both experimental data and existing numerical results.




**These Solutions** about a blunt cone with shock generators and a National Aerospace Plane (NASP) geometry were obtained with the algorithms: (a) shock shape comparison on a blunt cone geometry with shock generators and (b) atomic oxygen contours about a NASP-like configuration.

*This work was done by G. A. Molvik of MCAT Institute and C. L. Merkle of the Pennsylvania State University for* **Ames Research Center**. *Further information may be found in AIAA paper 89A-25174, "A Set of Strongly Coupled, Upwind Algorithms for Computing Flows in Chemical Nonequilibrium."*

*Copies may be purchased [prepayment required] from AIAA Technical Information Service Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 247-6500.*

*ARC-12676*

# Compliant Robot Wrist

Flexure elements are combined to give compliance along three axes, with or without rotation.

*Goddard Space Flight Center, Greenbelt, Maryland*

A compliant element for a robot wrist accepts small displacements in one direction only (to a first approximation, that is). Three such elements can be combined to obtain translational compliance along three orthogonal directions, without rotational compliance along any of them.

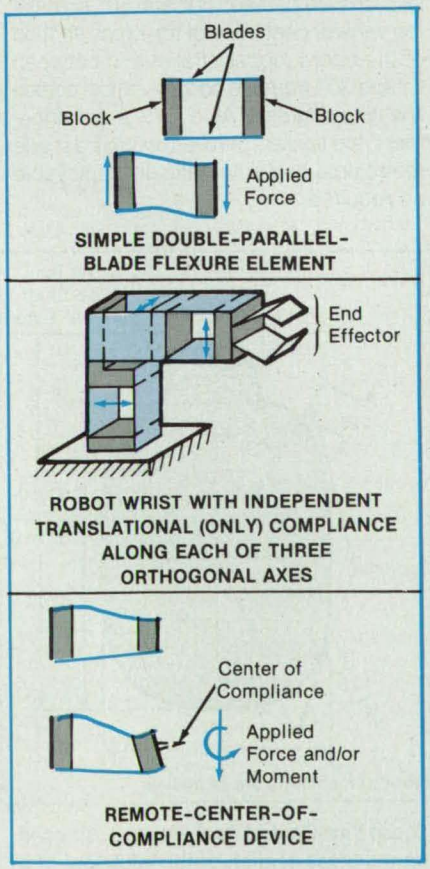
The element is a double-blade flexure joint in which two sheets of spring steel are attached between opposing blocks, forming a rectangle (see figure). The blocks can be moved parallel to each other in one direction only. The sheets act as double cantilever beams that deform in an S-shape, keeping the blocks parallel.

When three such elements are stacked so that their axes of compliance are orthogonal, the resulting device is rotationally stiff and permits only linear motion along the three axes. The compliance along each axis can be chosen by selection of the length, width, and thickness of the blades for that axis. Furthermore, the compliance and motion along each axis are uncoupled (to a first approximation) from those along the other axes.

If a compliant element is made with blocks of different sizes so that the blades are not parallel, the element becomes a remote-center-of-compliance device; that is, the center of compliance shifts to an outside point. The axis of rotation of the robot gripper can then be shifted to pass through this point, the location of which is determined by length of the blades and the distances between them at the two blocks.

Regardless of the specific geometry of a joint made of such elements, movement involves only bending: no rolling or sliding. Therefore, operation of the wrist does not produce wear particles, and the wrist is well suited for service in a vacuum system or in a clean room.

*This work was done by George Voellmer of* **Goddard Space Flight Center**. *No further documentation is available.*
*GSC-13357*




**Flexure Elements** can be combined to make a robot wrist compliant along one, two, or three axes.

# Enhancing Control of Helicopter Yaw at Low Speed

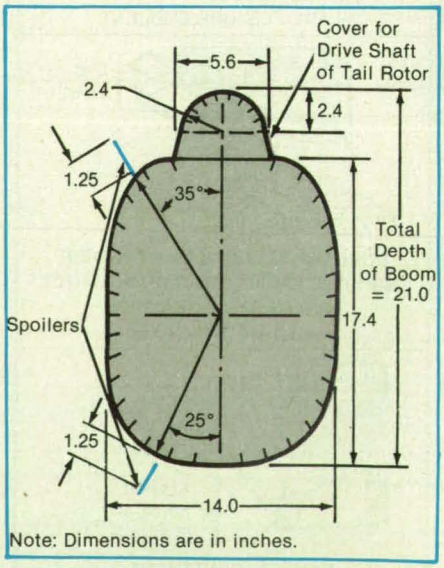
Spoilers on the tail boom significantly improve yaw control in both right and left sidewinds.

*Langley Research Center, Hampton, Virginia*

The tail booms of single-rotor helicopters are subject to significant aerodynamic loads in hovering and in low-speed flight. Major sources of the boom loads are induced aerodynamic effects from the main and tail rotors and from crosswinds. Previous techniques to improve yaw control include use of a circulation-control tail boom and use of a ducted fan in a large vertical fin. These techniques generally require more power and weight. The use of a single strake, previously developed at NASA Langley Research Center, has proven beneficial in hover and right crosswinds, but not in left crosswinds or left sideward flight. Consequently, an investigation of yaw control was conducted in the 14-by-22-ft (4-by-7-meter) wind tunnel at Langley Research Center, using models of tail booms in three representative shapes: those of the AH-64, UH-60, and UH-1H helicopters.

Two-dimensional aerodynamic forces and pressure distributions were obtained with large-scale models of the cross sections for flows at angles of incidence ranging from −45° to 90° and dynamic pressures ranging from 1.5 to 50 psf (0.072 to 2.4 kPa). The addition of spoilers to the booms at selected locations resulted in the shifting of the side forces in favorable directions over a wide range of flow angles. It was found that such additions spoil the airflow on a helicopter tail boom during hover and in right and left sidewinds so that less tail-rotor thrust and less yaw control are required. The result is a saving of power and an expanded range of crosswind conditions in which the helicopter can operate.

The spoilers are two thin plates that extend outward, perpendicular to the curvature of the boom, a distance of about 6 percent of the total depth of the tail boom (see figure). The along-the-boom dimensions of the spoilers are as long as possible without interfering with such existing critical parts as the tail rotor. For a single-rotor helicopter, the main rotor of which rotates counterclockwise viewed from above, as in the United States, typical strake locations are between 30° and 60° from the top vertical centerline of the cross section of the boom (upper strake) and between 0° and 30° from the bottom vertical centerline (lower strake). As a further enhancement, the spoilers (strakes) would be made retractable and automatically deployable as required.




These **Yaw-Control Spoilers** are positioned on the cross section of the tail boom of a UH-1H helicopter. Spoilers like these can be retrofitted to existing single-rotor helicopters or incorporated into new designs.

The tail-boom shapes studied constitute those of the bulk of the U.S. Army helicopter fleet. This spoiler concept should be applicable to all single-rotor helicopters. It can be applied as a simple economical addition to existing helicopters or incorporated into new helicopter designs.

*This work was done by Henry L. Kelley and John C. Wilson of* **Langley Research Center**. *Further information may be found in NASA TP-2506 [N-86-20349], "Aerodynamic Characteristics of Several Current Helicopter Tail Boom Cross Sections Including the Effect of Spoilers."*

*Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.*

*This invention has been patented by NASA (U.S. Patent No. 4,708,305). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-13630.*

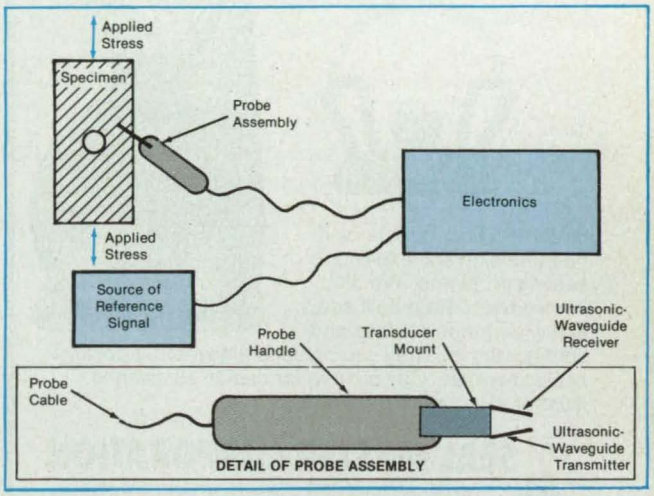
# Ultrasonic Dynamic Vector Stress Sensor

Stress is inferred from measurements in specimens rather than in bonded gauges.

*Langley Research Center, Hampton, Virginia*

The ultrasonic dynamic vector stress sensor (UDVSS) measures the changes in dynamic directional stress that occur in a material or structure at the location touched by the device when the material or structure is put under cyclic load. A typical prior strain-gauge device for the measurement of such a stress measured strain in itself, not in the part being strained, and thus provided a secondary measurement. Such other techniques as those that involve thermoelasticity and shearography have been expensive and placed demands on the measured material. The optical measurement of stress required the application of a phase coat to the object under test. The laser diffraction method required notching or sharp marking of the specimen.

The UDVSS is the first simple portable device able to determine stress directly in the specimen itself rather than in a bonded gage attached to the specimen. As shown in the figure, a typical material-testing machine applies cyclic stress to a specimen. The UDVSS includes a probe, which is placed in contact with the specimen; an electronic system connected to the probe; and a source of a reference signal. The probe assembly includes a probe handle that holds the probe; a transducer mount that contains an active ultrasonic driver and receiver; an ultrasonic-waveguide transmitter and an ultrasonic-waveguide receiver that convert the electrical signals to mechanical motion and the inverse, respectively; and a cable that connects the probe to the electronics. When in contact with the specimen, the ultrasonic-waveguide transmitter causes an acoustic wave to travel across the specimen to the ultrasonic-waveguide receiver, wherein the wave is converted to an electrical signal.




The **Ultrasonic Dynamic Vector Stress Sensor** includes a phase-locked loop, synchronous amplifier, and contact probe that, together, provide information on changes in stresses in the specimen.

The operation of the UDVSS is based on the fact that the propagation of sound in the specimen changes when the stress in the specimen changes. A pulsed phase-locked loop reacts to a change in propagation of sound and, therefore, in stress by changing its operational frequency. The ac component of that signal represents the change in voltage needed to keep the system at quadrature to follow the change in stress. That signal provides the information on changing stress.

The UDVSS can be moved around on the specimen to map out the stress field, and, by rotating the probe, one can determine the direction of stress. In addition, the probe is easily calibrated. The UDVSS should find wide acceptance among manufacturers of aerospace and automotive structures for stress testing and evaluation of designs.

*This work was done by Joseph S. Heyman and Mark Froggatt of* **Langley Research Center**. *For further information, Circle 22 on the TSP Request Card.*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14433.*

# Screens Would Protect Wind-Tunnel Fan Blades

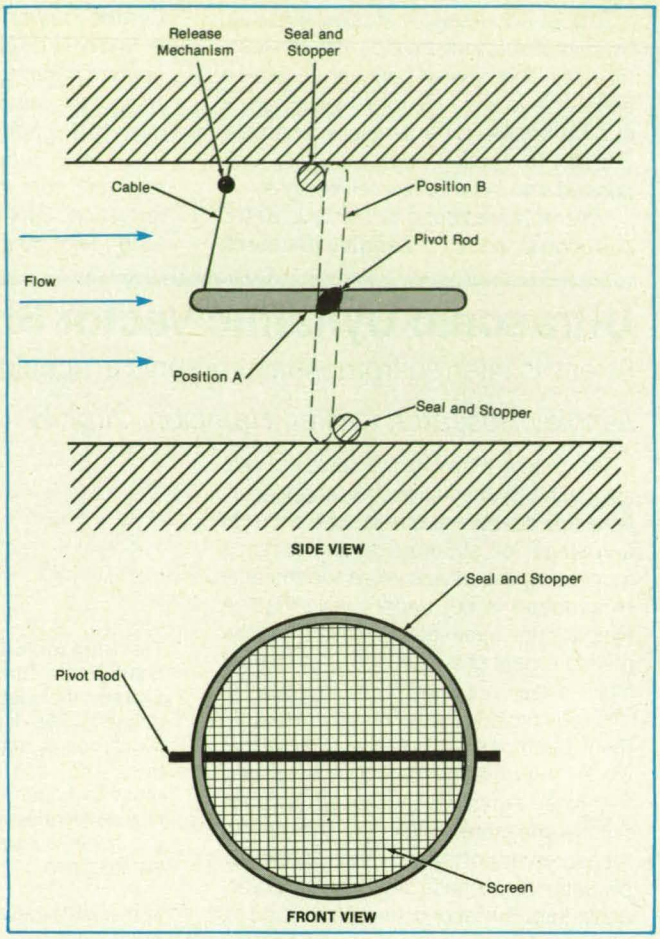
Protective screens could be deployed manually or automatically.

*Langley Research Center, Hampton, Virginia*

An automatically deployed fan-protection screen for a wind tunnel has been devised. The screen would protect wind-tunnel fan blades against damage from debris resulting from the breakup of the model or other mishaps in the tunnel.

The butterfly screen (see figure) would be installed in a wind tunnel between the test section and the fan blades to prevent debris from reaching the fan blades if the model structure fails. The screen would be supported by a horizontal pivot rod that would span the diffuser cross section. The screen would provide protection in position B. In the undeployed position, A, the leading edge of the screen would be held up by a cable attached to the ceiling. The screen could be ballasted to be nose-heavy and be positioned at a slightly negative angle of attack to keep tension in the cable.

The screen would be stored in position A when it is not needed. It could be moved to position B when the model being tested has a significant chance of structural failure or when a release mechanism in the cable is triggered. The seals around the walls of the diffuser would stop the screen at position B. With the screen in position B, the tunnel operation dynamic-pressure/mach-number envelope would be decreased. The release mechanism could be triggered by an electric signal that could be activated in a number of ways: manually by an observ-




The **Screen Could Be Deployed Quickly** to position B from storage in position A.

er who is closely watching the model, by a safety wire in the test apparatus that would open an electrical circuit upon breaking, or by an electronic detector that monitors a cross section of the diffuser just aft of the test section to detect flying debris.

This concept could be beneficial anywhere wind tunnels are employed. For example, it would also be potentially useful in areas outside of the aerospace industry, such as in the airflow design of automobiles and other vehicles.

*This work was done by Moses G. Farmer of* **Langley Research Center**. *No further documentation is available.*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14197.*

# Windshield-Wiper Heater

Heated blades significantly enhance safety of aircraft and automobiles.

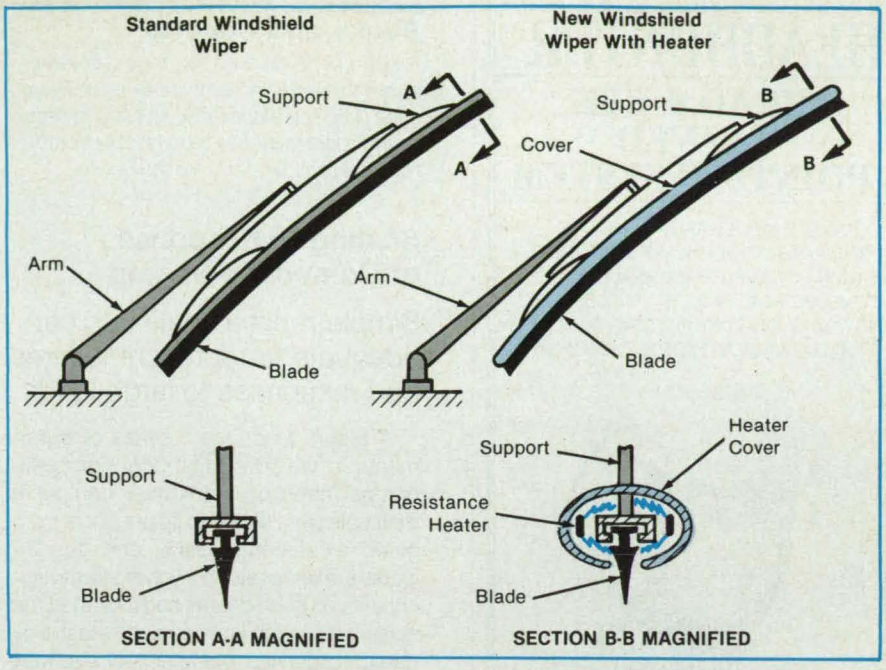
*Langley Research Center, Hampton Virginia*

The problem of removing snow and ice from aircraft and automotive windshields has been recognized for many years. In most vehicles, defrosting systems apply heat to the insides of the windshields. This heat may be able to prevent freezing and fog from obscuring vision in many situations, but some weather is too cold or too wet. In these cases, ice or snow accumulates on the windshield wipers, making them incapable of wiping the windshields cleanly. The result is unsafe situations. The windshield-wiper heater concept was designed to solve the problem, but has not yet been tested as of February 1992.

The windshield-wiper heater applies heat directly to the windshield wipers, preventing any ice or snow from accumulating on the wipers. A clear plastic heater cover (see figure) encloses the base of the wiper and its support. Electrical-resistance heater strips extend along the wiper inside the cover. The heat from the resistance strips warms the cover and flows down along the wiper blade. One end of the cover is removable to allow the blade to slide out for replacement. The entire cover could also be removable for easy access to the resistance strips and associated wiring.

The obvious advantage of the windshield-wiper heater is increased safety. The most common use would probably be in automobiles. Even more important, however, might be the use of the windshield-wiper heater in airplanes and trucks. Because the windscreens of commercial aircraft are kept at a temperature above 36 °F (2 °C) under all conditions, ice does not normally develop on them. However, small, private aircraft would benefit considerably, providing a significant safety feature for general aviation.

*This work was done by James A. Martin of* **Langley Research Center**. *No further documentation is available.*
*LAR-14426*




**Electrical-Resistance Heating Strips** inside the cover keep the wiper blade warmer than freezing temperature.

# Positive Stop for Circulation-Control Slot

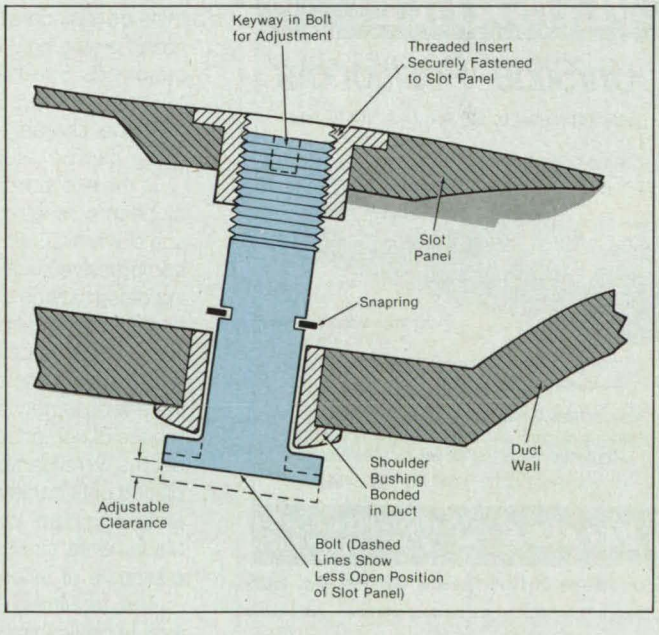
A rounded shoulder on a bushing ensures a repeatable stop position.

*Ames Research Center, Moffett Field, California*

An improved stop mechanism allows an airflow slot on a circulation-control airfoil to be limited to a precise width. The new stop mechanism replaces one in which the bolt was threaded into an insert in the duct wall and the other end was conical and nested in a countersunk hole in the slot panel. This configuration was unsatisfactory because, unless the bolt was perfectly aligned with the hole, the slot opening would continue to increase as the bolt attempted to seat itself. Moreover, the shank of the bolt chafed in the hole in the graphite slot panel, and the wear reduced the accuracy of the slot position as the pressure in the duct increased.

A shoulder bushing is installed in the duct so that its shoulder rests on the inside surface of the duct (see figure). The shoulder prevents the bushing from being dislodged by the stop forces and provides a stiffer stopping surface than does a sleeve bushing bonded in the duct wall. The contact surface of the shoulder is convex to minimize the motion of the slot due to misalignment of the contact.

A bolt is inserted through the bushing from below the duct. (A low-friction coating inside the bushing ensures smooth motion and minimal wear.) A snapring is slipped into a circumferential groove on the bolt to prevent the bolt from falling back into the duct. The bolt is turned by a key inserted in a keyway in the upper end of the bolt so that the threads of the bolt engage those of a threaded insert in the slot. The clearance between the head of the bolt and the face of the bushing is adjusted by turning the bolt after it has engaged the insert. The clearance is adjusted with the duct pressurized; this assures the proper opening when the duct deforms under pressure. The slot can then be opened and closed repeatedly; the width of the fully open slot remains fixed.




The **Bolt Slides in the Bushing** in the duct wall between more open and less open positions. There is no relative motion— and no wear—between the bolt and the slot panel.

*This work was done by David Hunter and Laurence Cullen of United Technologies, Sikorsky Aircraft, for* **Ames Research Center**. *For further information, Circle 70 on the TSP Request Card.*
*ARC-11764*

## Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

## Scaling of Responses of Composite Beams

### Simple replica scaling is not adequate to represent failures and responses to large loads.

A report describes a series of experiments in which scale-model composite beams made of matrix/fiber composite materials were tested to failure under combined axial compressive and bending loads. Earlier research involving transverse impacts on such beams had indicated that classical scaling laws apply to elastic dynamic responses, but effects of size were observed as the beams became damaged under greater impact loads. The current report discusses the scaling effects in the static large-deflection response of composite beams.

Scale-model technology represents one method of investigating the crashworthiness of advanced, weight-efficient composite aircraft components such as beams, frames, and rings. The report emphasizes the importance of understanding the limitations of scale modeling so that data from tests on subscale models will be valid for use in predicting the behaviors of full-scale prototypes. Scaling effects in the responses and failures of composite structures must be characterized before the technique can be used to full advantage.

In the experiments, eight different sizes of beams ranging from 1/6 scale to full scale were subjected to eccentric axial compressive loads to promote large bending deformations and failures. Beams that had different laminate-stacking sequences, including unidirectional, angle-ply, cross-ply, and quasi-isotropic, were tested to examine a wide variety of responses and failure modes of composite materials. The model beams were loaded under scaled test conditions until catastrophic failure occurred. Data acquired included loads, end displacements, strains, and qualitative measurements of failures.

The results of the tests indicate that simple replica scaling laws apply in the initial linear, small-deflection region of the response, but deviate as the response becomes nonlinear. Failure modes are consistent among scale models within a family of laminates, but a significant scale effect is observed in strengths of the beams. Small-scale beams fail at normalized loads that are higher, and normalized end displacements that are significantly higher, than those of full-scale prototypes.

The report concludes that an important scale effect exists in the modeling of failure behaviors of composite structures. It suggests that further work is required to identify the micromechanical mechanisms involved in this effect and to understand how they interact on a macroscopic level to produce the observed scale effect strength. It concludes that this phenomenon must be better understood before strength testing of scale-model composite structures can be utilized effectively.

*This work was done by Karen E. Jackson of* **Langley Research Center** *and Edwin L. Fasanella of Lockheed Engineering and Sciences Co. Further information may be found in NASA TM-101619 [N89-26843], "Scaling Effects in the Static Large Deflection Response of Graphite-Epoxy Composite Beams."*

*Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.*
*LAR-14366*

## Active Suppression of Vibrations in a Truss

### Research on a robust control system is described.

A report discusses recent and expected future developments in continuing research on the active suppression of vibrations in a truss structure. The experimental truss structure used in this research, the Precision Truss at NASA's Jet Propulsion Laboratory, has been described in previous articles in *NASA Tech Briefs*. The structure is intended to represent large, flexible structures to be erected in outer space.

The structure includes active members through which controlled oscillating forces can be applied to generate compensatory vibrations. It also includes load cells (force sensors) collocated with the active members, and accelerometers (vibration sensors) located elsewhere. This study focuses on the development of a digital controller as part of a vibration-suppressing feedback control system that includes the noncollocated vibration sensors and actuators. The controller is required to suppress vibrations in the presence of disturbances imposed from without. The control law is to be based partly on a dynamical model of the structure, actuators, and sensors; it is required to be robust in the mathematical sense that its performance should not be degraded significantly by errors and uncertainties in this model.

The noncollocation of sensors and actuators combines with a severe limitation on the amount of damping inherent in the structure to pose a challenging vibration-

suppression problem. In this study, the three control designs are derived by use of optimization procedures, then digitized and implemented on the experimental structure. Preliminary results of experiments are presented, and it is shown that there is some mismatch between predicted and measured performance. It is suggested that the cause of the mismatch should be investigated and the controller redesigned by use of a mathematical model based on experimental data. It is also suggested that the incorporation of passive dampers into the structure may enhance damping in the torsional vibration mode and help to suppress a potential instability that can arise from errors in the mathematical model.

*This work was done by Cheng-Chih Chu, Roy S. Smith, and James L. Fanson of Caltech for* **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Robust Control of an Active Precision Structure," Circle 97 on the TSP Request Card.*
*NPO-18305*

## Tests of Array of Flush Pressure Sensors

### Correlations between measured pressures and other operational parameters are investigated.

A report describes tests of an array of pressure sensors connected to small orifices flush with the surface of a 1/7-scale model of an F-14 airplane in a wind tunnel. The tests were part of an effort to determine whether pressure parameters that consist of various sums, differences, and ratios of the measured pressures can be used to compute accurately the free-stream values of stagnation pressure, static pressure, angle of attack, angle of sideslip, and mach number. If so, then such arrays of sensors and the associated processing circuitry could be integrated into advanced aircraft as parts of flight-monitoring and -controlling systems.

Pressures were measured at 23 orifice locations: 11 in a cruciform pattern on a spherical tip that blended smoothly with the nose tip of the fuselage, 4 in a ring around the nose behind the tip, and 8 in another ring farther back from the tip. Tests were performed at several speeds near mach 0.73 and at mach numbers of 0.90, 1.05, 1.20, and 1.39; at angles of attack from −4° to 20° in increments of 2°; and at sideslip angles from −8° to 8° in increments of 4°. The report displays the test data in tables and graphs of the various pressure parameters as functions of the mach numbers and the angles of attack and sideslip.

The stagnation pressures computed from those pressure parameters that were designated for this purpose were found to

lie within 1 percent of the stagnation pressures determined by independent wind-tunnel means when the local flow angles were zero. The pressure parameters designated for use in computing static pressures were found to vary with the mach number and with the angle of attack. One pressure parameter designated for use in computing the angle of attack was judged to offer the best compromise between desired and undesired attributes, with large sensitivity to the angle of attack, linear variability with the angle of attack, and small variability with the mach number.

The pressure parameters designated for use in computing the angle of sideslip behaved similarly to those designated for computation of the angle of attack. The sensitivities of these parameters to changes in the angle of sideslip were greatest for those parameters in this group that were based on nose-cap pressures.

Two types of pressure parameters were designated for use in computing the mach number. The one parameter of the first type is a ratio of between nose-cap pressures, while the two parameters of the second type are ratios between a nose-cap pressure to simulate stagnation pressure and fuselage pressures. The parameters of the second type were found to be better because they are less sensitive to the angle of attack, and more sensitive to the mach number.

*This work was done by Larry J. Larson of Analytical Mechanics Associates, Timothy R. Moes of* **Ames Research Center**, *and Paul M. Siemers III of Langley Research Center. Further information may be found in NASA TM-101697 [N90-18395], "Wind-Tunnel Investigation of a Flush Air-data System at Mach Numbers From 0.7 to 1.4."*

*Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.*
*ARC-12869*

## Habitable Wardroom for Space Station Freedom

### Concepts, models, mockup, and prototypes are described.

Two reports and two patents describe a study of concepts for the wardroom in the proposed Space Station Freedom. In the first phase of the study, the researchers developed nine architectural concepts as scale models for the space station "group habitability module" and evaluated them on the basis of ergonomic, functional and human-factors criteria. In the second phase, the researcher team designed and constructed three distinct, full-scale space station wardroom mockup concepts. The researchers evaluated their candidate concepts according to 57 design factors organized into the following factor groups:

- Architecture,
- Utility systems,
- Architectural subsystems,
- Perceptual quality,
- Ergonomics,
- Wardroom activities,
- Associated features,
- Crew orientation to local vertical,
- Crew translation through the wardroom, and
- Use by subgroups of the crew.

Based on the detailed evaluation of these three concepts, the team focused their attention on a single concept, drawing upon the innovative features of all three full-scale mockups. A final full-scale mockup was constructed of durable components for easy demonstration and exhibition and for shipment to other locations for further review and evaluation. Additionally, the researchers developed and built high-fidelity prototypes of specific crew equipment. These prototypes include a wardroom table, a portable and wearable computer workstation, and a passive leg restraint.

This architectural design research produced a wardroom concept intended for use by the crew of Space Station Freedom for meetings, training sessions, video conferences, recreation, the preparation and eating of food, and cleanup after meals. The wardroom must be comfortable, efficient, and habitable to foster a high level of day-to-day crew productivity and sustained, reliable performance on missions lasting 90 days or longer.

The final concept mockup divides the Space Station habitability module, containing the wardroom, into an upper and lower level of accommodation. This dual-level configuration improves operational and translational efficiency and enhances perceptual interest.

Utility systems are organized into routes running parallel to the longitudinal axis of the module. These utility channels serve equipment racks and compartments located along their length and are incorporated into the spines of the structural support system within the module. The racks and compartments in the final wardroom mockup are curved to optimize their interior volumes and to enhance the perception of spaciousness within the module. The wardroom contains adequate free volume to accommodate as many as 16 people during an exchange of crews at the completion of one tour of duty and the beginning of the next tour.

The wardroom mockup includes deployable and retractable crew activity compartments and exercise spaces. These tentlike compartments may be stowed when not in use to allow more volume to be available. The translation routes through the module are clearly defined so that the crewmembers can move about safely and efficiently. A distinct floor plane and visual references provided by the structural members help crewmembers orient themselves to the local vertical. Hand holds attached to the substructure and equipment provide mobility and restraint aids throughout the mockup.

The central focus of the wardroom architecture is the multipurpose wardroom table. This table design benefited from extensive crew activity, anthropometric analysis, and ergonomic analysis. The table can accommodate a crew shift of four with the deployable leaves in their compact position or the full baseline crew of eight with the leaves extended. These extendable leaves constitute individual work surfaces that the crew can deploy to accommodate a wide range of uses and comfort preferences. The wardroom table design includes provisions for task lighting, stowage, and hand restraints.

The prototype portable/wearable computer workstation can be extended outward in front of the crewmember's body during use and folded inward when not in use to give the user more room to move about the Space Station. This workstation would provide a comfortable, convenient, and compact facility for communication, data management, and audiovisual functions. The prototype passive leg restraint is designed to stabilize the body without attachments or muscular tension in a relaxed microgravity posture. The researchers tested both the portable/wearable workstation and an early version of the passive leg restraint in simulated weightlessness during a parabolic flight regime on a KC-135 aircraft.

*This work was done by David Nixon, Christopher Miller, and Regis Fauquet of the Southern California Institute of Architecture and Jan Kaplicky of Future Systems, Inc., for* **Ames Research Center**. *Marc M. Cohen of Ames Research Center was the technical monitor and a coinventor. Further information may be found in NASA CR-4010 [N87-21585], "Space Station Group Activities Habitability Module Study;" NASA CR-4246 [N90-17308], "Space Station Wardroom Habitability and Equipment Study;" U.S. Patent 4,836,114, Space Station Wardroom Table; and U.S. Patent 4,865,270, Passive Zero-Gravity Leg Restraint.*

*Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.*
*ARC-12762*

# Improved Superconducting Magnetic Rotary Bearings

Lateral adjustments compensate for weight and other side loads.

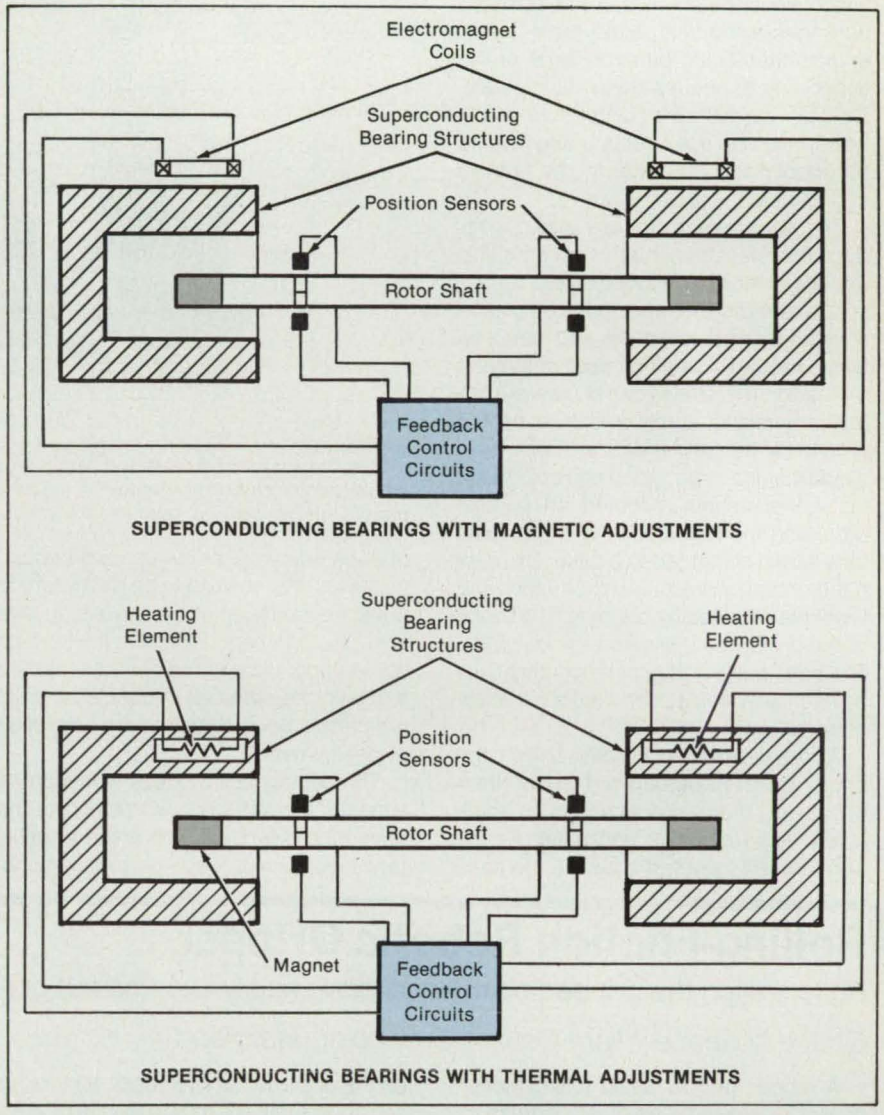
*Goddard Space Flight Center, Greenbelt, Maryland*

Improved magnetic rotary bearings can be designed by exploiting the properties of type-II superconducting materials. Depending on the particular design and application, a bearing of the new type can provide fixed or adjustable compensation for the lateral (that is, perpendicular to the axis of rotation) vector component of the weight or other lateral load on the rotor.

A type-I superconductor exhibits perfect diamagnetism at an applied magnetic field up to some critical value, above which superconductivity is lost and the magnetic field penetrates. A type-II superconductor allows an applied magnetic field to penetrate it partially in clusters of field lines, with the concomitant establishment of undamped circulating electrical currents within the material. Type-II superconductors have critical magnetic fields and critical (superconducting-transition) temperatures greater than those of type-I superconductors; the type-II superconductors include the well-known ceramic compound $YBa_2Cu_3O_x$ and other, lesser-known ceramics based on thallium and bismuth.

A rotor supported magnetically according to the general concept (see figure) includes two axially polarized permanent-magnets, one at each end of the rotor shaft. A superconducting bearing structure confines each end of the shaft, leaving a little room for lateral movement. Each end of the shaft is thus levitated diamagnetically by interaction with the superconducting bearing structure; in effect, suspended by a magnetic cushion within the bearing structure.

Lateral displacements of, and loads upon, a shaft can be counteracted in any of several ways, all of which involve the introduction of compensatory asymmetries into the levitating magnetic fields. In the examples shown in the figure, the vertical positions of the ends of a horizontal shaft are sensed electronically to detect any deviation of the shaft from the designated centerline; the position signals are processed through feedback control circuits that adjust the magnetic fields to force the shaft back toward the centerline. In the first example, the adjustment is made via electromagnet coils atop the bearing structures. In the second example, the adjustment is made by applying varying amounts of heating power to the top sides of the superconducting bearing structures to decrease the degree of type-II superconductivity asymmetrically by an amount that compensates for the weight of the rotor.




**Magnetic Rotary Bearings** that include structures made of type-II superconductors can be adjusted magnetically or thermally.

In another method (not shown in the figure) for adjusting the lateral positions of the ends of the shaft, each superconducting bearing structure could be divided into quadrants, which could be adjusted mechanically. Fixed compensation for lateral loads could be provided by bearing structures in which type-II superconductivity is distributed asymmetrically via asymmetrical shape, the use of two different type-II superconductors, or both.

*This work was done by Yury Flom and James Royston of* **Goddard Space Flight Center**. *For further information, Circle 57 on the TSP Request Card.*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 20]. Refer to GSC-13346.*

# Foldable Large Reflectors

A reflector would be deployed from an approximately cylindrical package about one-fifth as wide.

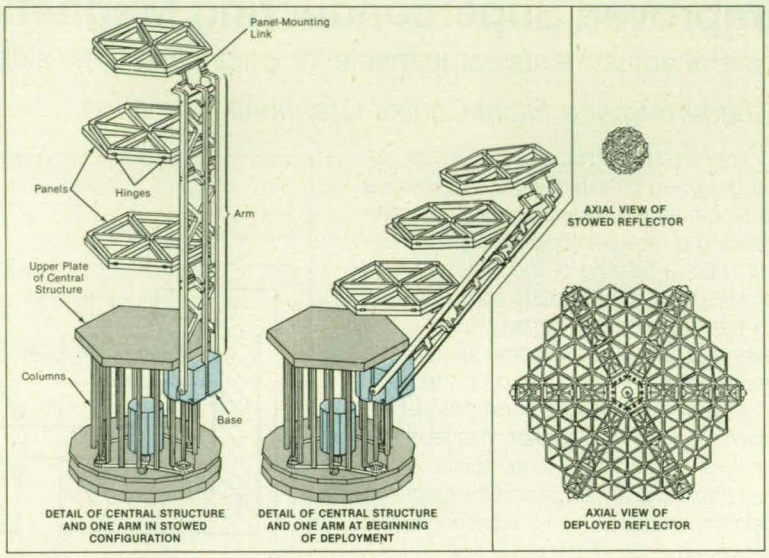
*Langley Research Center, Hampton, Virginia*

Large paraboloidal, otherwise curved, or flat reflectors (e.g., solar or radio reflectors) would be automatically deployable from, and retractable into, compact packages, according to a proposal. The reflecting surfaces would consist of rigid panels, which would be stacked in the compact packages along with deployment mechanisms that would become parts of the supporting structures upon deployment. Typically, the diameter of a reflector of this type in the deployed configuration would be about five times that in the stowed configuration.

The deployment process would introduce minimal strain in the members during deployment and would yield an accurate reflecting surface upon completion of deployment. Deployment and retraction would require a small number of motors.

The figure illustrates one of several alternative versions. Arms would be nested around a central structure. Each arm would include three folded pairs of hinged hexagonal panels mounted on parallel bars, and the lower ends of the parallel bars would be hinged to a base. The central structure would consist of upper and lower plates joined by columns. The bases of the arms would slide on the columns. The bars, base, and panel-mounting links on each arm would constitute a parallelogram linkage.

As the deployment process began, the arms would pivot outward about their bases until they came to rest at an angle a few degrees above horizontal. As the arm elements pivoted outward, the base of each one would slide upward through whatever distance would be necessary to bring the surfaces of the panels on that arm into alignment, flush with the surface of the upper plate of the central structure and with the surfaces of panels on adjacent arms, upon subsequent completion of deployment.




In the **Deployment Sequence**, arms would rotate outward, and hinged double panels would unfold. When fully deployed, the panels would constitute a paraboloidal surface. The panels, shown here as open trusses, would be covered to present a reflecting surface.

The deployment process would be reversible. The direction of rotation of the drive motors would be reversed to refold the hinged panels, pivot the arms to return to their original vertical orientation, and slide the bases of the arms downward on the columns to stow the reflector in its compact, approximately cylindrical configuration.

*This work was done by Martin M. Mikulas, Jr., of* **Langley Research Center** *and Charles Hoberman of Honeybee Robotics. For further information, Circle 41 on the TSP Request Card.*
*LAR-14513*

# Rolling-Friction Robotic Gripper

Rollers align the gripped object and move easily into and out of engagement.

*Goddard Space Flight Center, Greenbelt, Maryland*

A robotic gripper using rolling-friction fingers closes in on an object with an interface designed to mate with the rollers that may be somewhat misaligned initially, aligns the object with respect to itself, then holds the object securely in a uniquely determined position and orientation — that is, holds it without rattle. The operation of the gripper causes minimal wear and burring of the gripper and object. Because the gripper makes only rolling contact with the object, it exerts minimal friction forces on the object when grasping and releasing it, and releases the object easily and reliably even when there are side forces and torques between itself and the object.

The gripper (see Figure 1) is mounted on the end effector of a robot. It includes two fingers that are moved toward or away from each other by a mechanism in a gripper housing. Each finger includes a large centering roller aligned along the $z$ axis and four clamping rollers aligned along the $y$ axis.

The object to be grasped could be, for example, a handle on a tool that is to be manipulated by the robot. It is sized and shaped to mate with the gripper; specifically, it includes two large recesses to engage the two centering rollers and four sets of seating ramps to engage the four clamping rollers.

Figure 2 presents an example of what happens when the fingers close in on an object that is initially tilted somewhat out of alignment. First, one or both of the centering rollers make contact with the surfaces of the recesses in the object, causing the object to rotate about the $z$ axis toward the proper alignment. Next, the seating ramps make contact with one or more of the clamping rollers, causing the object to rotate about the $x$ and $y$ axes. The fingers move inward until all the clamping rollers are seated firmly against all the seating ramps. In that configuration, the grasping forces on opposing rollers are equal, and the object is restrained against translation or rotation in any direction.

*This work was done by John M. Vranish of* **Goddard Space Flight Center**. *For further information, Circle 72 on the TSP Request Card.*

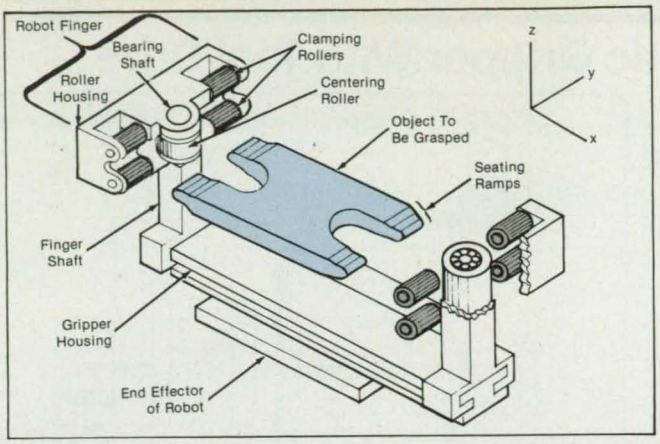



Figure 1. **Rollers in the Fingers** come to rest against seating ramps when the fingers close in on the object to be grasped. The rollers keep friction low, correct initial misalignment of the object, and grip the object securely.

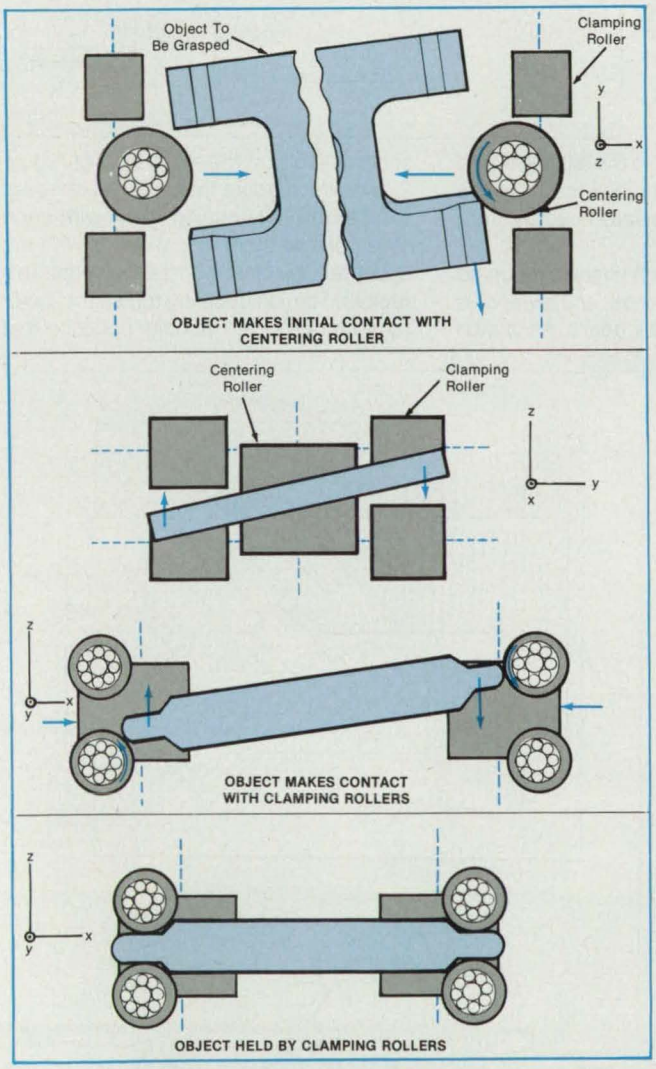



Figure 2. **Upon Initial Contact With the Rollers**, the object begins to rotate toward its prescribed orientation.

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 20]. Refer to GSC-13261.*

# Split-Rail, Rolling-Friction Robotic Gripper With Tool Drive

The split-rail drive effects the gripping motions.

*Goddard Space Flight Center, Greenbelt, Maryland*

The robotic gripper shown in Figure 1 includes a split-rail drive assembly that moves two gripping fingers toward or away from each other. The gripping fingers are equipped with rollers that mate with recesses and seating ramps on a specially designed object. They are similar, in design and operation, to those described in the preceding article, "Rolling-Friction Robotic Gripper" (GSC-13261). In addition, the present gripper includes a rotary tool that operates on a mechanism in the gripped object.

The split-rail drive assembly includes an upper rail and a lower rail that move, relative to each other and relative to a rail housing, on cylindrical, crossed roller bearings (see top part of Figure 2). The left (in Figure 1) finger is mounted on the upper rail. A stepping servomotor and harmonic drive turn an acme a nut in the harmonic-drive housing, causing an acme screw to advance to the right or left. The left end of the acme screw is connected to a ball joint in an end piece on a rib that extends from the left finger. The advance of the lead screw is coupled to the left finger and upper rail through this joint, causing the left finger to move toward or away from the right finger.

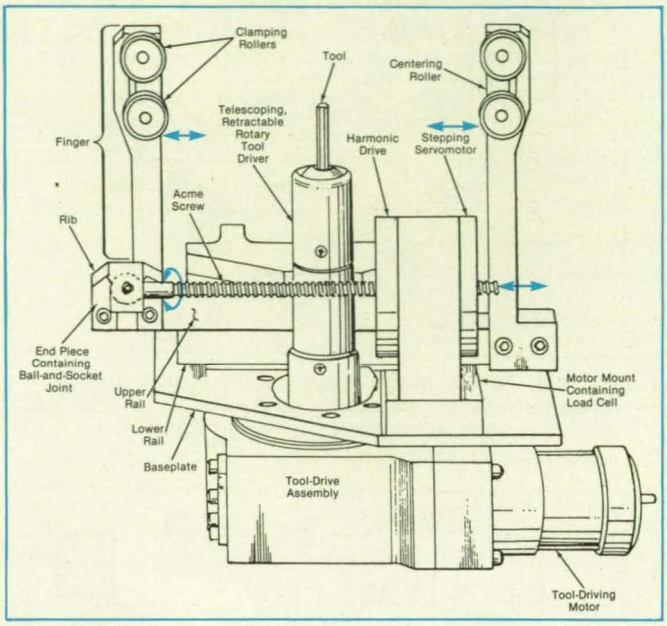



Figure 1. This **Robotic Gripper** includes two rolling-friction gripping fingers, a split-rail drive, and a retractable rotary tool.

The right (in Figure 1) finger is mounted on the lower rail. The upper and lower rails are equipped with rack gears. As shown schematically in the lower part of Figure 2, two pinion gears that rotate about axes fixed in the rail housing mesh with each other; one of them also meshes with the upper rail, the other with the lower rail. This rack-and-pinion coupling forces the lower rail to move at the velocity opposite that

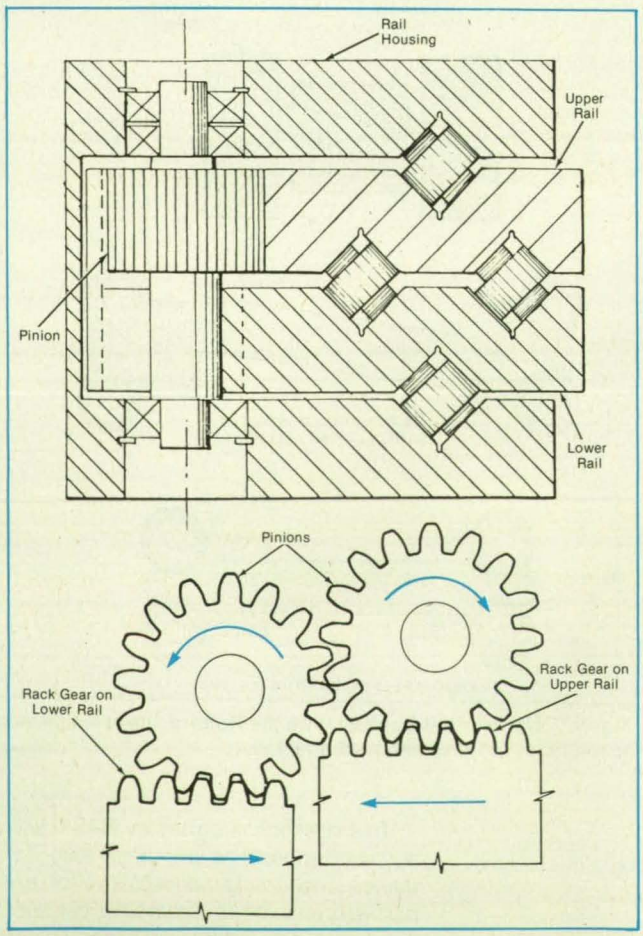



Figure 2. The **Rails Move on Cylindrical, Crossed Roller Bearings**. The upper rail drives the lower rail via rack-and-pinion coupling.

of the upper rail: specifically, when the upper rail is driven to the right (in Figure 1), the lower rail moves to the left and both fingers move inward, closing in on the object to be gripped. When the upper rail is driven to the left, the lower rail moves to the right, so that both fingers move outward to release the object.

The mount that supports the stepping motor and harmonic drive contains a load cell that measures the gripping force exerted by the fingers (as coupled through the acme screw and the drive/stepping-servomotor assembly). This measurement could be used as a feedback signal to control the force.

The rotary tool is powered by a motor and drive assembly mounted under the split-rail drive assembly. The tool extends upward from a telescoping, retractable driver. The tool is retracted during grasping and releasing motions. Once the object to be grasped is gripped securely between the fingers, the tool can be extended.

*This work was done by George M. Voellmer of* **Goddard Space Flight Center**. *For further information, Circle 10 on the TSP Request Card.*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 20]. Refer to GSC-13370.*

# Electrically Controlled Valve With Small Motor

The lifting effect of a stretched cable pulled sideways multiplies the available force.

*Lyndon B. Johnson Space Center, Houston, Texas*

The design of an electrically controlled valve exploits a force-multiplying principle to overcome the large back-pressure force that resists initial opening. This design makes it possible to open the valve by use of a relatively small motor that is adequate for the rest of the valve motion, but that would otherwise not be large enough to open the valve.

The force-multiplying principle is well known. It is that of an incline, the slope of which increases gradually from zero. In a simple linear lifting configuration based on this principle (see Figure 1), small horizontal forces are applied to a pair of taut cables to lift a large weight through a short distance. In a rotary lifting configuration, a similar effect is achieved by rotating, about an axis, a disk to which initially axial cables are attached.

The operation of the valve is based on the rotary version of the lifting principle, and is illustrated in simplified schematic form in Figure 2. The poppet is mounted on a ferromagnetic rotor that is suspended axially by three cables. Permanent magnets are mounted on the periphery of the rotor in nonmagnetic cups (not shown). The rotor is part of a brushless dc permanent-magnet motor. The stator of the motor is mounted on the outside of the valve housing, which is not ferromagnetic. A ring containing permanent magnets pulls the rotor axially so as to tend to seat the poppet; that is, to tend to close the valve. When the valve is closed, the pressure from the inlet (the back pressure) increases the closing force that must be overcome in opening the valve.

The valve is opened by energizing the stator to apply torque to the rotor. As the rotor turns, it twists the cables away from their axial orientation, thereby lifting the rotor and the poppet axially, away from the valve seat, against the closing forces of the magnets and back pressure. The motor is part of a microprocessor-controlled feedback loop

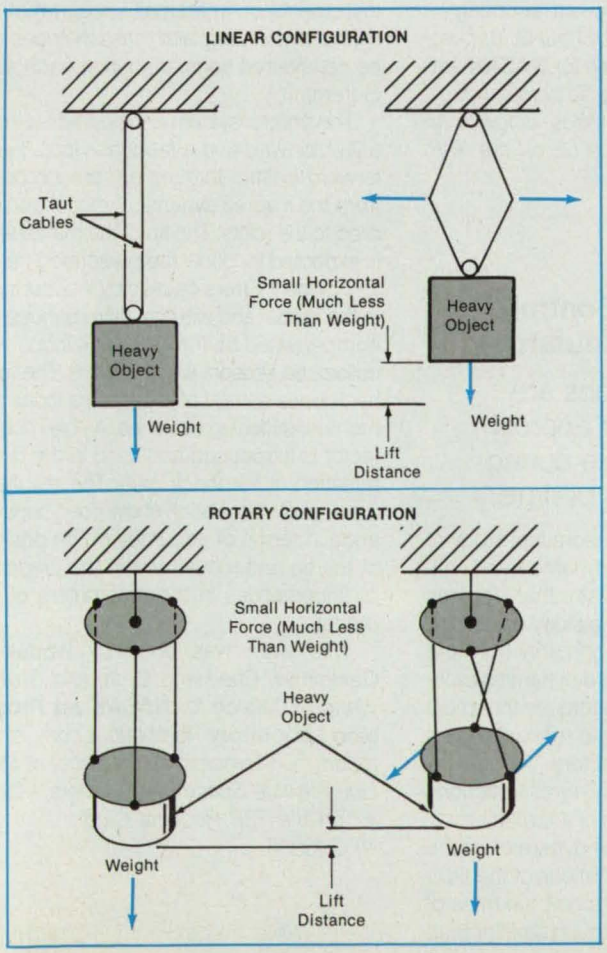



Figure 1. The **Application of Small Lateral Forces** to taut cables makes the cables exert large longitudinal forces. In the ideal case of perfectly flexible (but not stretchable) cables, the force-multiplication factor is infinite at infinitesimal lateral deflections or rotations.

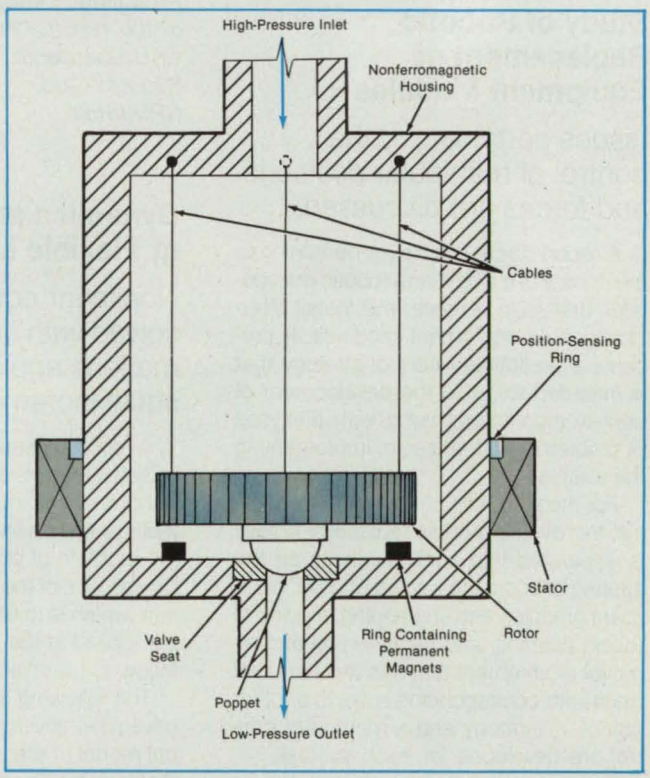



Figure 2. The **Electrically Controlled Valve** is shown here greatly simplified to illustrate the principle of operation. As the rotor turns, the twisting of the cables pulls it axially toward the inlet end, thereby opening the valve.

that is used to regulate the amount of rotation and, thereby, regulate the opening of the valve and the amount of flow. A position-sensing ring in the stator contains Hall-effect sensors that detect the passage of permanent magnets in the rotor. The outputs of the position sensors are compared with a commanded-position signal, and the current applied to the motor is adjusted to move the motor toward the commanded position.

*This work was done by Robert H. Reinicke, Rafic Mohtar, and Richard O. Nelson of Eaton Corp. for* **Johnson Space Center**. *For further information, Circle 108 on the TSP Request Card.*

*Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457(f)], to the Eaton Corporation. Inquiries concerning licenses for its commercial development should be addressed to*

*Eaton Corporation*
*Valve & Actuator Division*
*2338 Alaska Ave.*
*El Segundo, CA 90245-4896*

*Refer to MSC-21665, volume and number of this* NASA Tech Briefs *issue, and the page number.*

## Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

## Study of Robotic Replacement of Equipment Modules

### Issues pertaining to the control of manipular positions and forces are discussed.

A report discusses issues pertaining to the control of a single-arm robotic manipulator that is to remove and install interchangeable equipment modules. It presents a preliminary control strategy that is intended to guide the development of control algorithms, along with analyses of problems that arise in implementing the strategy.

For the purposes of strategy and analysis, the overall module-replacement task is separated into such subtasks as the seating of bolts, the turning of bolts, compliant grasping and ungrasping, moving to touch, pushing, and the insertion and removal of an object that has two pins that mate with corresponding holes in another object. A strategy and a method of control are developed for each subtask.

One of the principal control issues arises from the fact that most of the subtasks involve control of contact between the manipulator and an object. If only position control (that is, without force control) were used, even small errors in mathematical models, the outputs of position sensors, and/or the outputs of position actuators could give rise to large forces at points of contact. Even with perfect mathematical modeling and position control, flexibility of a manipulated object or of another object in the environment could prevent completion of a task if only position control were used.

Therefore, the preliminary control strategy calls for the use of active compliance and force control to control the contact forces. The computations for this purpose are performed concurrently in both a Cartesian coordinate frame and in robot-joint space. The contact forces and position errors are first measured in Cartesian space. Cartesian-space-position and force control updates the desired position of the manipulator in a coordinate frame attached to the terminal link of the manipulator. Then proportional/integral/derivative control is used in the joint space to move the manipulator to the desired position.

The preliminary control strategy was tested on a six-degree-of-freedom robotic manipulator, with emphasis on the subtasks of seating and turning bolts and inserting and removing the object that has two pins that mate with corresponding holes. The latter subtask requires a decision-based strategy in conjunction with compliant control to prevent jamming.

*This work was done by Paul G. Backes and Kam S. Tso of Caltech for* **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Autonomous Single-Arm ORU Changeout," Circle 62 on the TSP Request Card.*
*NPO-18152*

## Dynamics and Control of Flexible Manipulator

### Nonlinear equations are solved with linear approximations applicable during small increments of time.

A report presents a theoretical study of selected aspects of the dynamics and control of a robotic manipulator that includes multiple flexible links. The study addresses the problem of control primarily from the perspective of the inverse-dynamics problem, which is to find the torques that must be applied at the joints to make the links follow a specified trajectory.

The following simplifying assumptions govern the development of the mathematical model of the inverse dynamics of the manipulator. The deformations of the flexible links are elastic and small; the rates of rotation of the links are much smaller than are the natural vibrational frequencies of the deformations; the nonlinear terms (those that represent the centrifugal and Coriolis forces) in the mathematical model of the flexible manipulator equal the corresponding terms in the mathematical model of the otherwise equivalent rigid manipulator.

The development of the mathematical model begins with the conventional finite-element matrix•vector formulation of the equations of motion. The deformations are expressed as displacements from the rigid-body configuration. Two inverse-dynamics problems are considered. The first one is to find the joint torques that eliminate the error between the actual and commanded trajectories. The inverse dynamical model obtained by the solution of this problem is found to be unstable and sensitive to variations in the parameters of the model.

The second inverse-dynamics problem is to find the joint torques that make the joint angles of the flexible manipulator equal those of the otherwise identical rigid-link manipulator. The inverse dynamical model obtained by solution of this problem is found to be stable and robust in the presence of errors in the model.

The remainder of the paper discusses an approach to position control based on the solution of the second problem. Invoking the assumption that the vibrational frequencies greatly exceed the rotational frequencies, the model is made piecewise linear in time by choosing the successive increments of time small enough that the stiffness, damping, and mass matrices can be considered constant during each such increment.

The control system considered includes a feedforward and a feedback loop. Feedforward control torques are precomputed from the inverse dynamical model and applied to the joints. The tip of the manipulator is expected to follow the prescribed trajectory closely. Errors caused by inaccuracies in the model and external disturbances are compensated by the feedback loops with collocated sensors and actuators. The feedback loops consist of joint-control loops and member-stiffening subloops. A pole-mobility factor is introduced and used in the determination of feedback gain. The results of a computer simulation show good performance in terms of accuracy of the position of the tip and robustness in the presence of uncertainties in the parameters of the model.

*This work was done by Wodek K. Gawronski, Che-Hang C. Ih, and Shyh J. Wang of Caltech for* **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "On Dynamics and Control of Multi-Link Flexible Space Manipulators," Circle 47 on the TSP Request Card.*
*NPO-18338*

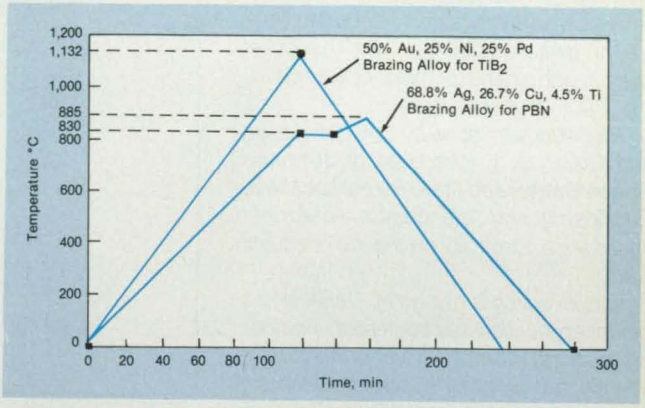
# Joining Ceramics by Brazing

Brazing would enable many configurations to be assembled from parts of limited shapes.

*Lewis Research Center, Cleveland, Ohio*

Certain ceramic materials can be tightly bonded together by brazing with suitable alloys. In a demonstration of this concept, two flat pyrolytic boron nitride (PBN) samples were bonded by use of a 0.002-in. (0.005-cm)-thick foil of brazing alloy that had a composition of 68.8 percent Ag, 26.7 percent Cu, and 4.5 percent Ti; and two flat titanium diboride ($TiB_2$) samples were bonded by use of a brazing alloy that had a composition of 50 percent Au, 25 percent Ni, and 25 percent Pd. Thus, brazing can enable the fabrication of parts of a wide variety of shapes from smaller initial pieces of ceramics that can be produced directly in only a limited variety of shapes. (Currently, the chemical-vapor-deposition technique used to form PBN and the hot-pressing technique used to form $TiB_2$ limit the possible shapes of initial pieces of these ceramics.)

In one of the experiments of the demonstration, flat pieces of PBN and its brazing alloy were cleaned by soaking in a container filled with acetone and then placed in an ultrasonic cleaner for 20 min. The brazing material was placed between the pieces of PBN and inserted into a vacuum furnace, which was pumped down to less than $2.66 \times 10^{-4}$ Pa ($2 \times 10^{-6}$ torr) before heating. The sandwich of PBN and alloy foil was brazed at a temperature of 885 °C according to the heating schedule shown in the figure. The furnace was heated to, then held for 20 min at, the solidus temperature of the alloy (830 °C) to enable the sandwich specimen to come into thermal equilibrium with the furnace. Then the furnace was heated further for 20 min to bring it up to the brazing temperature of 885 °C, which is 35 °C above the liquidus temperature of the alloy. It was held at this temperature for 2 min, then cooled to room temperature in approximately 2 h. Upon removal of the specimen from the furnace, it was readily apparent that excellent wetting had occurred between the PBN and brazing alloy.




These **Heating Schedules** were used to braze pieces of PBN with an Ag/Cu/Ti alloy and for brazing pieces of $TiB_2$ with an Au/Ni/Pd alloy.

Next, a PBN lid and crucible were brazed together along the "c" axis in a similar manner and connected to a helium leak detector through a hole in the crucible. No leaks greater than $1 \times 10^{-9}$ standard mL/s of He were observed. However, repeated thermal cycling between room temperature and 700 °C in air caused the rate of leakage to increase; after 15 cycles, the leak rate was $1 \times 10^{-5}$ standard mL/s.

The figure also shows the heating schedule according to which two flat pieces of $TiB_2$ were bonded with the applicable gold-based alloy in another experiment. This sandwich of $TiB_2$ and alloy foil was brazed in a vacuum furnace at 1,132 °C for 1 to 2 min, then cooled to room temperature in 2 h. Excellent wetting was observed between the $TiB_2$ and the alloy. A $TiB_2$ lid was brazed to a $TiB_2$ crucible, and leak tests were again performed before and after thermal cycles between room temperature and 700 °C. Even after 15 cycles, no leaks greater than $1 \times 10^{-9}$ standard mL/s of He were observed.

*This work was done by Francis P. Chiaramonte and Michael W. Sudsina of* **Lewis Research Center**. *For further information, Circle 76 on the TSP Request Card.*

*LEW-15291*

# Robot Would Assemble Collet/Flexible-Drive Truss Joint

Actuation would require only simple motions.

*Lyndon B. Johnson Space Center, Houston, Texas*

A proposed truss joint is designed expressly for assembly by a robot. The joint would be "robot-friendly" in that it would require only simple motions of the end effector of the robot, would tolerate relatively large initial misalignment of the strut, and could be successfully assembled with little feedback. Developed for the Space Station, the joint could also be used for robotic construction in hazardous or undersea locations — oil rigs, for example.

The joint would connect a strut to a node ball. A node ball would accommodate several joint/strut combinations to form a truss. Principal features of the joint are that an expanding collet would latch it to the node ball and that the collet would be expanded by a flexible drive shaft operated by the robot.

A node ball would contain a "scar" — a protrusion that would contain a receptacle — for each strut to be joined to it (see figure). The robot would grasp the joint and bring its anterior end close to the scar receptacle so that a capturing guide on the joint would clasp a collar on the scar, thereby keeping the scar and joint in axial alignment during further assembly operations.

The robot would insert the flexible drive into the joint through an access hole and push it axially, forcing the collet and inner plunger assembly into the scar receptacle, compressing the retraction spring as it does. The robot would exert torque on the flexible drive shaft, which would screw the threaded shaft toward the anterior end. This action would advance the expander rod, the tip of which would expand the collet, securing it in the receptacle. The flexible shaft would continue to drive the threaded shaft a little farther to compress the stack of Belleville washers, thus preloading the joint. Finally, the robot would extract the flexible shaft from the assembled joint.

During assembly, the joint would be rotated about its axis to a fixed azimuthal relationship with the aid of a pin on the scar collar that would engage a key on the end of the joint. Clocking would enable the joint

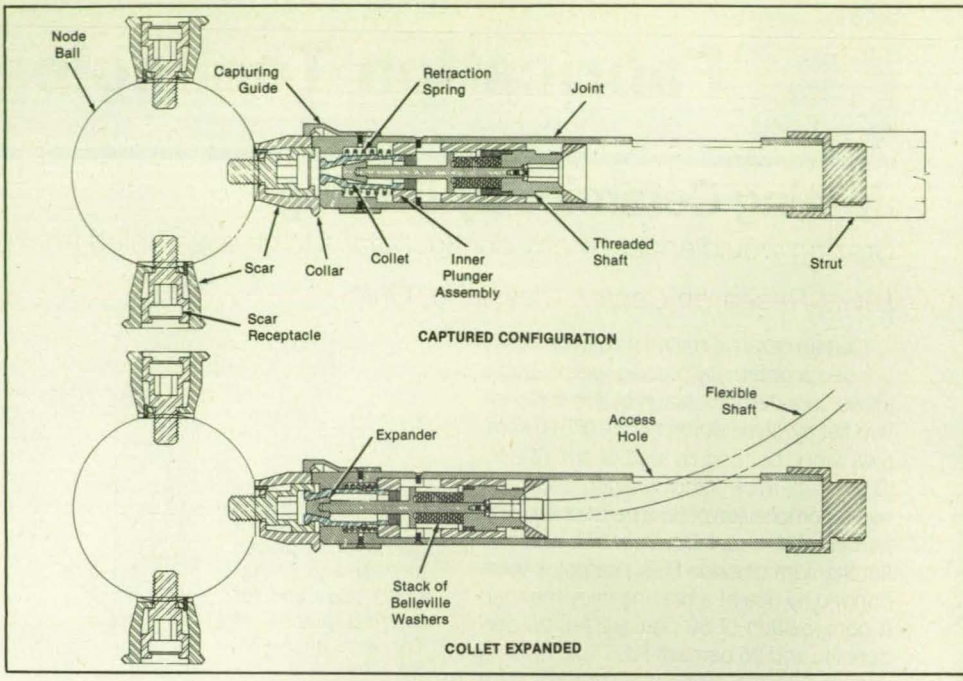
to resist torsional loads.

The joint could readily be disassembled. The robot would insert the flexible shaft and unscrew the threaded shaft, releasing the preload and retracting the expander rod. The robot would remove the flexible shaft. The inner plunger assembly would return to its posterior position under the force of the expanding retraction spring. The robot would then remove the joint from the scar.

In an emergency, a human could assemble or disassemble the joint. A socket wrench with a hand- or motor-operated flexible shaft would be used.

*This work was done by Erik E. Evenson and Clarence J. Wesselski of* **Johnson Space Center** *and Steve Ruiz of Lockheed Engineering and Sciences Co. For further information, Circle 87 on the TSP Request Card.*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 20]. Refer to MSC-21648.*




The **Robot Would Bring the End of the Joint** in contact with the scar so that the scar collar would be captured (top). The robot would then use the flexible drive shaft to engage the expandable collet in the receptacle in the scar (bottom).

# Making Conductive, Compliant Heat-Transfer Pads

## The pads are composites of copper and tungsten.

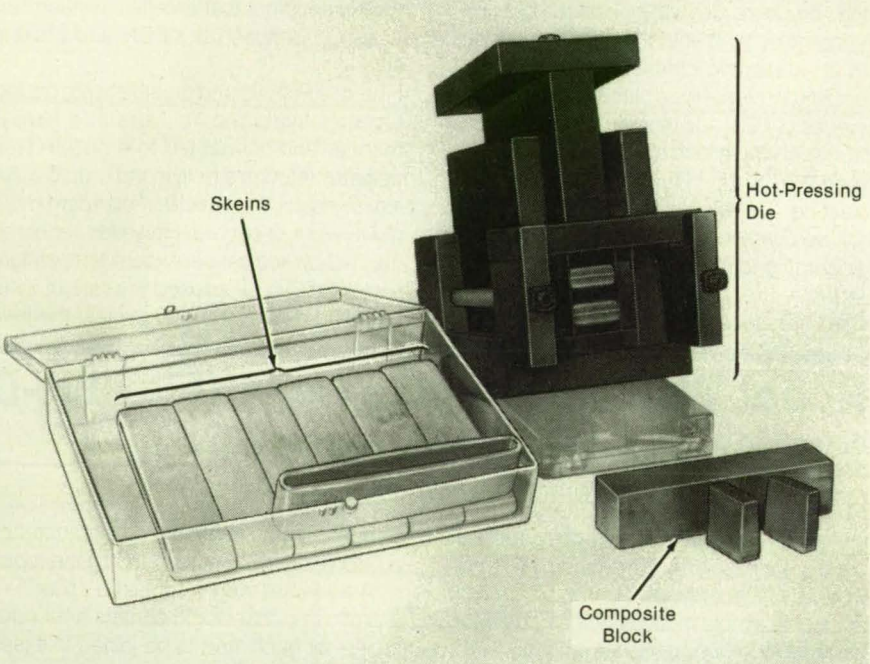
*NASA's Jet Propulsion Laboratory, Pasadena, California*

Composite copper/tungsten pads have been developed for use in thermoelectric generators. These pads are thermally and electrically conductive and compliant enough to accommodate large mismatches in thermal expansion between different parts. Each pad consists of tungsten fibers in a copper matrix interconnecting a pair of tungsten face sheets.

The raw material for fabrication of the pads is a combination wire that consists of a tungsten wire around which copper wire has been wrapped. The combination wire is wound onto a flat graphite spool fixture at a controlled pitch to a preset number of wraps on a winding machine. The skein of combination wire thus formed is removed from the machine and fired in hydrogen at a temperature of 850 °C to sinter the wires so that they remain in the same relative positions in the skein.

The sintered skein is removed from the spool, placed in a graphite-lined molybdenum die (see figure), and vacuum-hot-pressed to make the copper flow together and squeeze out all the voids. The resulting composite block has the required composition and density. This part of the process is easy to carry out and relatively inexpensive. The size of the blocks can be changed simply by changing the size of a graphite insert in the die.

The block is sliced into pads by electrical-discharge machining (EDM). The pads are etched in nitric acid to expose the ends of the tungsten wires to a length of 1 to 2 diameters. Finally, the face sheets are formed by chemical-vapor deposition of tungsten onto the exposed wire faces. The copper matrix material is then leached out in nitric acid leaving the tungsten fibers and face sheets.




The **Tongue-and-Groove Graphite Die** is used in hot-pressing sintered skeins of copper-wrapped tungsten wire into composite tungsten/copper blocks.

*This work was done by Lawrence E. Douglas of General Electric Co. for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 107 on the TSP Request Card.*
*NPO-18562*

# Artificial Intelligence Assists Ultrasonic Inspection

Subtle indications of flaws are extracted from ultrasonic waveforms.

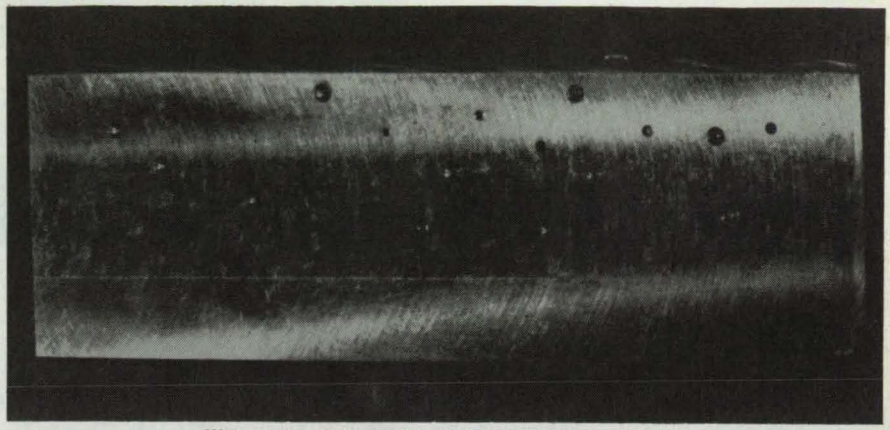
*Marshall Space Flight Center, Alabama*

An ultrasonic-inspection system uses artificial intelligence to help in the identification of hidden flaws in electron-beam-welded castings. The system involves the application of flaw-classification logic to the analysis of ultrasonic waveforms.

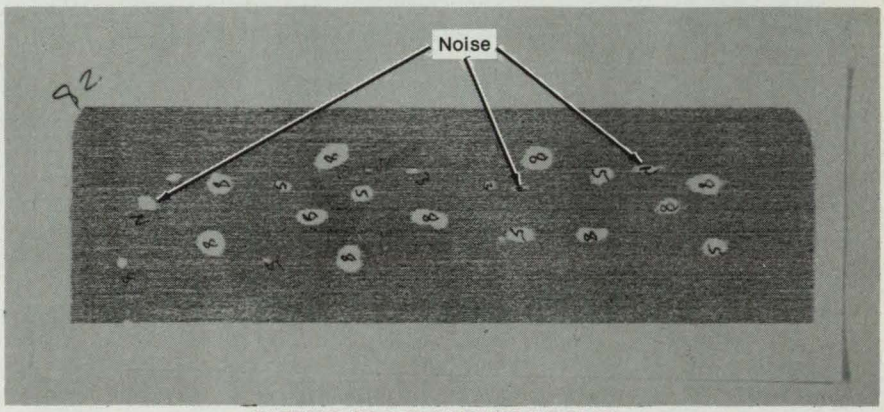
Conventional C-scan presentation of ultrasonic-inspection signals is not suitable for an electron-beam-welded casting because variations in the sizes of grains in the casting give rise to acoustically sensible inhomogeneities that are difficult or impossible to distinguish from flaws (see figure). X-ray inspection is not effective because it does not resolve the closely spaced flaws characteristic of electron-beam welds. The new system, however, can extract subtle indications of flaws from noisy ultrasonic signals.

When a welded specimen is scanned ultrasonically, the system compares the measured waveforms with those in a data base that consists of experimentally collected ultrasonic waveforms from representative flaws. The system classifies the waveforms according to Gaussian, Fischer-linear-discriminant, and K-nearest-neighbor rules. The system then decides probabilistically which patterns represent flaws.

In tests, the new ultrasonic system successfully discriminated 98 percent of the time between flaw signals and the attenuation noise characteristic of structurally sound portions of an electron-beam-welded casting 1.5 in. (3.8 cm) thick. Artificial flaws in the form of flat-bottom holes of diameters from 3/64 in. (1.2 mm) to 1/8 in. (3.2 mm) were discriminated in initial efforts with rates of success ranging from 85 to 92 percent. Further improvement is expected as the flaw-classifier data base grows larger.



WELDED CASTING WITH FLAT-BOTTOM HOLES




ULTRASONIC C-SCAN FROM SURFACE OPPOSITE THAT SHOWN ABOVE

The **Ultrasonic C-Scan** of this electron-beam-welded casting shows the pattern of flat-bottom holes but also includes noise that resembles the indications of holes.

*This work was done by Lloyd A. Schaefer and James D. Willenberg of Rockwell International Corp. for* **Marshall Space Flight Center**. *For further information, Circle 94 on the TSP Request Card.*
*MFS-29817*

# In Situ Robotic Inspection of Welds

An automated system reduces delays in inspection and rework.

*Marshall Space Flight Center, Alabama*

A robotic system inspects a robot-welded workpiece for internal flaws before it is removed from the welding stage. The workpiece can thus be reworked immediately, if necessary. Previously, it was necessary to remove the workpiece from the welding stage for inspection and to reinstall the workpiece on the welding stage if rework was required — a procedure that typically lasted several days.

The robotic inspection system reduces the inspection-and-rework delay from days to hours. The path of the inspection sensors is taken directly from the welding path; this saves time in programming for inspection. The inspection data are stored so that they are not lost as soon as the inspection equipment is turned off.

The same robot that welds the workpiece is used to inspect it. In preparation for inspection, the welding tool mounted on the end effector of the robot is replaced with an eddy-current or ultrasonic sensor (see figure). [If the workpiece is more than 0.06 in. (1.5 mm) thick, the ultrasonic sensor is used.] The robot recalls the welding path from memory and retraces it, recording the sensor output as it proceeds.

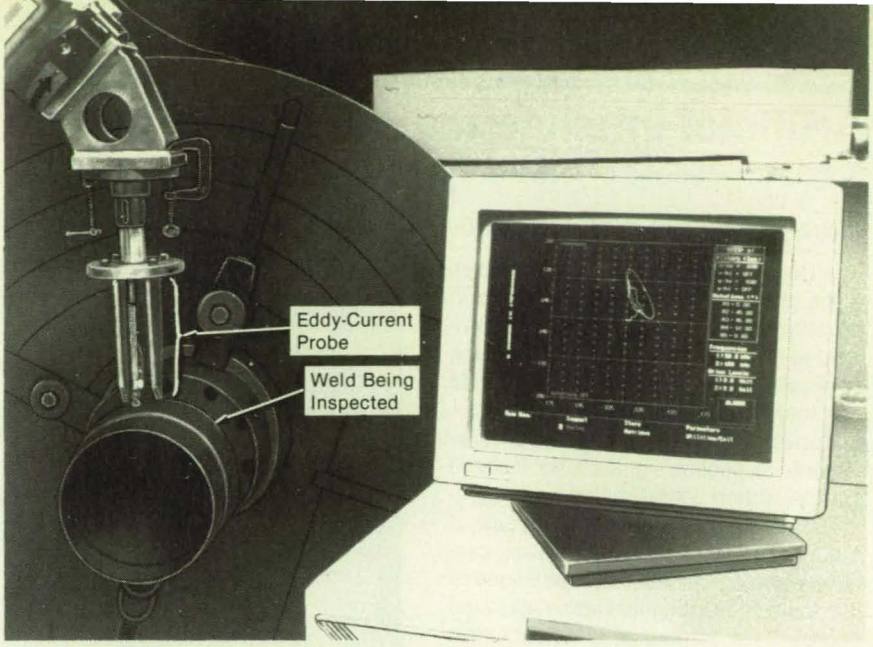
The inspection system includes a personal computer that contains a circuit board that digitizes the output of the sensor. A classifier — a software catalog of flaws and characteristics of sensor waveforms associated with the flaws — is applied to the sensor output. Waveform-analysis software transforms the time-domain digitized sensor waveform into the frequency domain, as required for use in the classifier software. Values for 108 signal features are extracted from the digitized data, and these values are compared statistically to the classifier data. If a flaw is found, its location, size, and type are recorded. At the end of the inspection, the system prints out the data.

Expert-system software manages the data, performs the analyses, and produces the inspection report. Inspection of just

one weld may require dozens of inspection points and requires full analysis of the waveform at each point.

*This work was done by Lisa M. van Wyk, Raul C. Garcia, Jr., and Jeffrey L. Gilbert of Rockwell International Corp. for* **Marshall Space Flight Center**. *For further information, Circle 80 on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-29844.*




The **Eddy-Current Probe** is mounted on the end effector of the robot and rolls along the weld on wheels. The video screen shows a representative eddy-current display.

# Modified Spot Welder Solders Flat Cables

## High-temperature solders can be melted without damaging insulation.

*Goddard Space Flight Center, Greenbelt, Maryland*

A soldering device that is essentially a modified spot welder melts high-melting-temperature solders without damaging the plastic insulation on flat electrical cables. The device is used to solder flexible ribbon cables to subminiature pin connectors.

High-melting-temperature solders have greater resistance to thermal fatigue and are therefore preferred for cables that are subjected to extensive thermal cycles. Until now, to prevent overheating during soldering and the consequent damage to insulation, fabricators of cable assemblies have been limited to solders that melt at about 183 °C or less; for example, an alloy of 63 percent tin and 37 percent lead, which has developed cracks after only 10,000 cycles from −40° to +40 °C. With the new soldering device, such solders as 92.5 percent lead, 5 percent indium, and 2.5 percent silver, which melts at 310 °C and has superior resistance to thermal fatigue, can be used.

As a soldering device, the modified welder protects the cable insulation from melting and burning at such high temperatures through the control of the heat input to the parts and the rapid removal of heat from the insulation. Instead of welding two parts together, the welder applies a controlled force to a solder preform between a pin of a connector and a conductor of a flexible ribbon cable (see figure). The welder then sends a controlled electrical pulse through the preform.

The pulse travels down one of the electrodes of the welder, through the pin, and into the preform and conductor (see figure). The pulse returns from the conductor and preform and passes through the pin and into the opposite electrode. The heat from the pulse briefly melts the preform so that it bonds with the pin and connector.

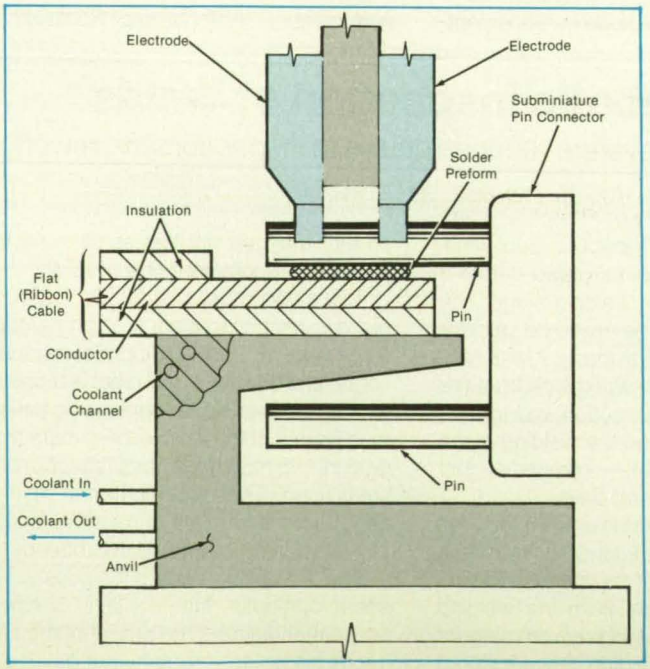
The next pin, solder preform, and conductor are moved into position under the electrodes. The process is repeated until all conductors in the cable have been joined to connector pins.

The proper settings — electrode force, rate of increase of current, rate, peak current, and pulse time, for example — must be determined for the particular combination of cable, preform, and connector. Samples should be made at selected settings and tensile-tested until the best combination of conditions for maximum strength, without damage to insulation, is found.

The anvil that supports the cable during soldering can be made of aluminum or other thermally conductive material. The anvil contains channels through which cooling air or water flows and thus conducts heat rapidly away from the insulation to minimize heating.

*This work was done by Carl L. Haehner of* **Goddard Space Flight Center**. *For further information, Circle 37 on the TSP Request Card.*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 20]. Refer to GSC-13344.*




The **Solder Preform Rests on the Exposed Conductor** of the cable, under a connector pin. The electrodes press the pin/preform/conductor sandwich together and supply a pulse of current to melt the preform, bonding the pin to the conductor. The anvil acts as a support and heat sink.

# Laser Shearography Reveals Hidden "Unbonds"

Flaws can be identified faster than in ultrasonic inspection.

*Marshall Space Flight Center, Alabama*

A holographic technique detects hidden "unbonds" — areas within metal heat exchangers, graphite/epoxy laminates, or other structural components in which adjacent layers that are supposed to be bonded together are not, in fact, bonded together. The holographic technique, known as laser shearography, does not require elaborate provisions for the suppression of vibrations, unlike other holographic techniques. It is fast, scanning 1 square foot (about 0.1 square meter) of surface area in only 1 second, compared to 6 minutes for conventional ultrasonic inspection. Moreover, unlike ultrasonic techniques, laser shearography can be used to inspect complexly contoured surfaces.

The part to be inspected is placed in the field of view of the laser-shearographic apparatus (see Figure 1) and is illuminated by laser light while it is pressurized or otherwise stressed. The portions of the observed surface that overlie the unbonds are deflected by the applied stress more than are the portions that overlie the well-bonded areas. The reflected, focused image of an unbond appears as a pair of bright spots on the image plane (see Figure 2). The number of interference fringes around the spots indicates the amount of deflection that, in turn, is related to the size of the unbond.

*This work was done by Lloyd A. Schaefer of Rockwell International Corp. for* **Marshall Space Flight Center**. *For further information, Circle 49 on the TSP Request Card.*
*MFS-29814*

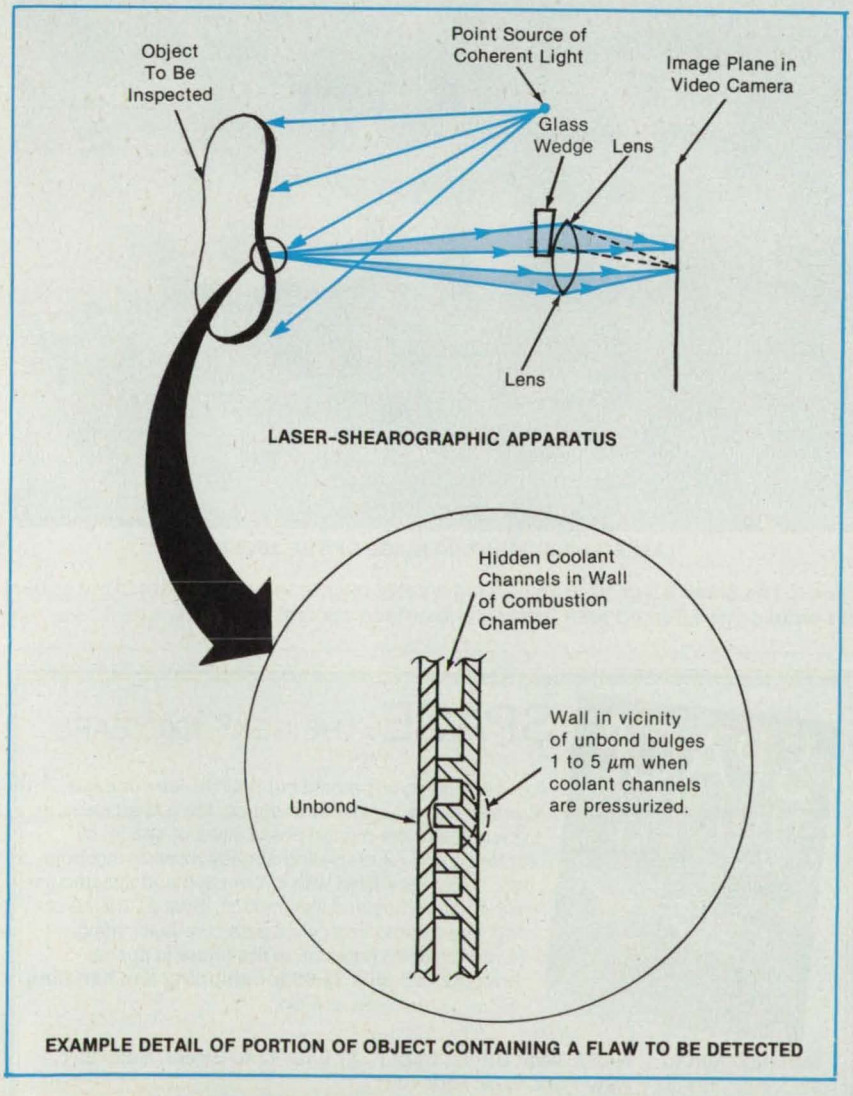
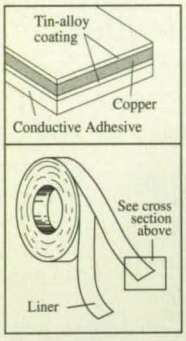



Figure 1. The **Laser-Shearographic Apparatus** is used to observe an object while a stress is being applied. The shearographic image is indicative of deflection caused by the stress.

# 3M Reveals New Long Term EMI/RFI Shielding Tape

## Tin-alloy coating on both sides of copper foil offers superior solderability, environmental stability.

AUSTIN, Tex. — This new UL Recognized Scotch™ Foil Shielding Tape 1183 employs a tin-alloy coating on smooth copper foil to produce a durable and effective electromagnetic shield.




The tin-alloy coating is on both sides of the copper for thorough protection.

The tape is a tin-alloy coated version of the widely used 3M 1181 Tape and provides shielding when wrapped around flat and round cable, and cable connectors.

The unique electrically-conductive adhesive enables 1183 tape to make electrical connections across seams and between mating sections, of electronic enclosures ranging from small equipment housings to large shielded rooms. The tape can also shield the energy radiating from seams between the sectors of dish antennas.

The special tin-alloy coating on both sides of the foil provides two significant benefits.

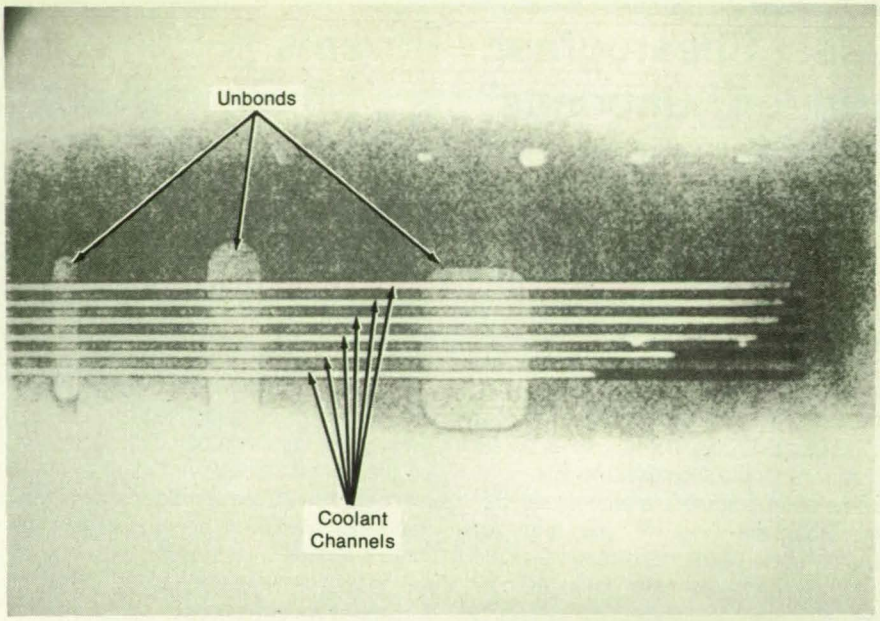
1. Thorough environmental stability and corrosion resistance.
2. Exceptional solderability for applications such as sealing the seams when the tape is used as a shield around cable connectors.

3M 1183 Tape also serves as a corrosion resistant contact surface for conductive gasketing, beryllium copper "spring fingers" or other resilient conducting media used around doors and openings of electronic cabinetry.

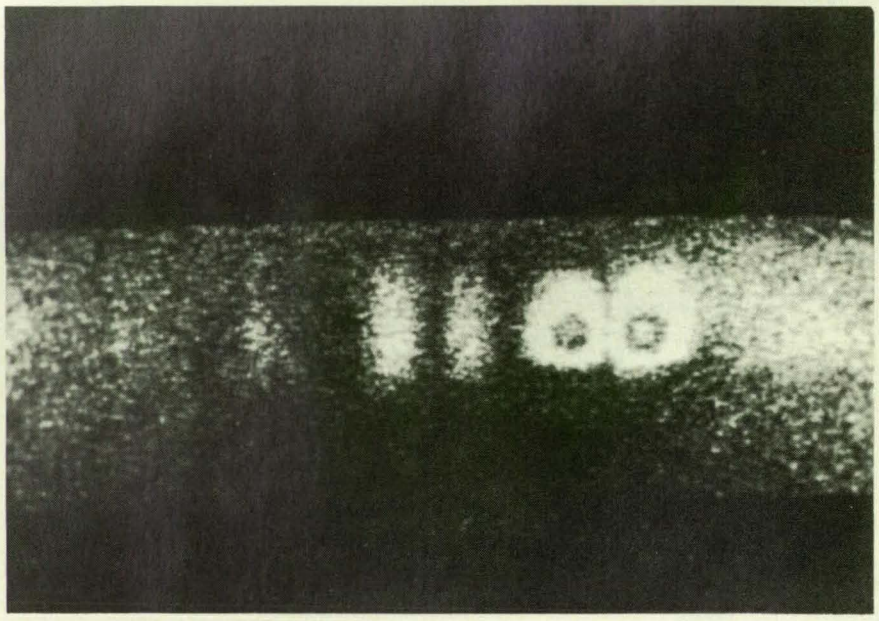
For more information about all 3M Foil Tapes, contact a 3M Electrical Specialties Division representative or authorized distributor or call 1-800-328-1368.

**3M Electrical Specialties Division**
6801 River Place Boulevard
Austin, Texas 78726-9000

3M




**RADIOGRAPH SHOWING UNBONDS DELIBERATELY INTRODUCED INTO LANDS BETWEEN HIDDEN COOLANT CHANNELS AS REFERENCE STANDARDS FOR ULTRASONIC INSPECTION**



**LASER-SHEAROGRAPHIC IMAGE OF THE ABOVE**

Figure 2. The **Small Bulge** from an unbond creates an interference pattern in the optical field around the affected area (here, a subsurface coolant channel).

# Mathematics and Information Sciences

## Hand/Eye Coordination for Fine Robotic Motion

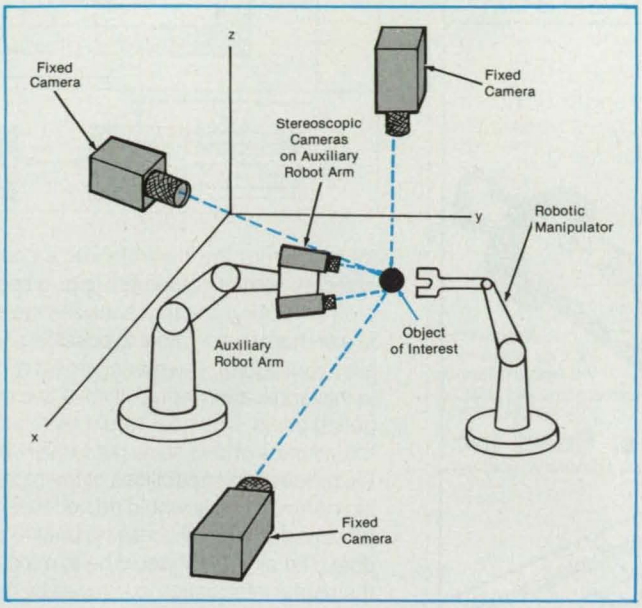
An absolute coordinate frame and extensive calibration are not necessary.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

The fine motions of a robotic manipulator can be controlled with the help of visual feedback by a new method that reduces position errors by an order of magnitude. The errors — typically of the order of centimeters — are differences between real positions on the one hand and measured and computed positions on the other hand; these errors arise from several sources in the robotic actuators and sensors and in the kinematical model used in control computations. In comparison with prior methods of controlling the motion of a robot with visual feedback (the robotic equivalent of hand/eye coordination), the novel method requires neither calibration over the entire workspace nor the use of an absolute reference coordinate frame for computing transformations between field-of-view and robot-joint coordinates.

The robotic vision subsystem includes five cameras: three stationary ones that provide wide-angle views of the workspace and two mounted on the wrist of an auxiliary robot arm to provide stereoscopic closeup views of the workspace near the manipulator (see figure). The vision subsystem is assumed to be able to recognize the object(s) to be avoided and manipulated, and to generate data on the coordinates of the object(s) from sensed positions in the field-of-view reference frames.

The new method can be implemented in two steps. In the first step, the closeup stereoscopic cameras are set initially to view a small region that contains an object of interest. The end effector is commanded to move to a nominal position near the object and within the field of view.




**Stereoscopic Cameras** on an auxiliary robot arm give closeup views of the object and end effector. These cameras measure errors between commanded and actual positions and/or provide data for mapping between visual and manipulator-joint-angle coordinates.

Typically, the manipulator stops at a slightly different position, which is measured by the cameras. Then the measured error in position is used to compute a small corrective motion. This procedure is designed to exploit the fact that small errors in relative position can be measured accurately and small relative motions can be commanded accurately.

In the second step of the method, one develops an approximate direct mapping between the visual coordinates and the manipulator joint-angle coordinates, without intermediate transformation to and from absolute coordinates. This is, in effect, a calibration, but it requires fewer points than does a conventional calibration in an absolute reference frame over the entire workspace. The calibration is performed by measuring the positions of a target (in field-of-view coordinates) when the target is held rigidly by the manipulator at various commanded positions (in manipulator-joint-angle coordinates) and when the cameras are placed at various commanded positions. Interpolations and extrapolations to positions near the calibration points are thereafter performed by use of the nominal kinematic transformations.

*This work was done by Anatole M. Lokshin of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 25 on the TSP Request Card.*
*NPO-18316*

## Dynamic Restructuring of Problems in Artificial Intelligence

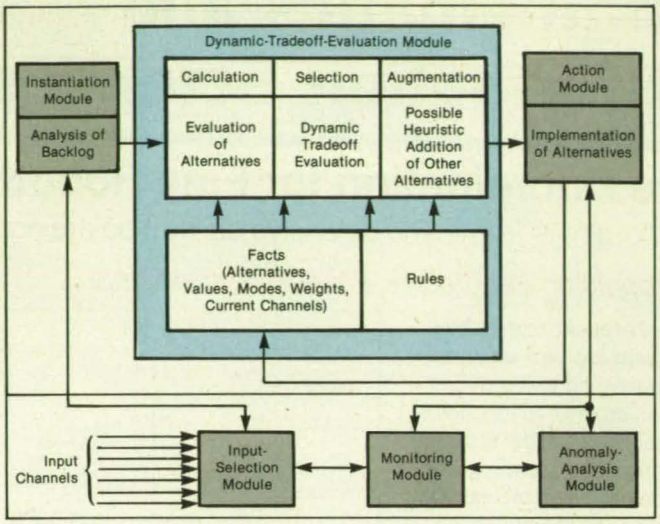
Tradeoffs among nonoptimal strategies would satisfy the need for timely action.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

"Dynamic tradeoff evaluation" (DTE) denotes a proposed method and procedure for restructuring problem-solving strategies in artificial intelligence to satisfy the need for timely responses to changing conditions. The essence of the DTE approach as applied to a given system would be to (1) detect situations in which optimal problem-solving strategies cannot be pursued because of real-time constraints, and (2) effect tradeoffs among nonoptimal strategies in such a way as to minimize the adverse effects upon the performance of the system.

DTE is based on multiattribute utility theory (MAUT), a branch decision theory. MAUT is used to make "one-shot" decisions in static environments. DTE involves a knowledge-based extension of MAUT that makes it suitable for highly dynamic real-time environments. In DTE, utility theory is used to rank alternatives in a preference space, and heuristic decision rules are used at run time to (1) dynamically reweight the attributes of individual alternatives and (2) dynamically select among preference criteria in the preference space, depending on the attributes of the situation and the modes of operation.

DTE is best explained by use of an example of its application to a specific problem: managing the streams of input data flowing to an artificial-intelligence system




**Dynamic Tradeoff Evaluation** would be performed by one module of an artificial-intelligence computing system that would monitor multiple channels of data from a complicated system of equipment.

that monitors the operation of a complicated system of equipment (e.g., a spacecraft or factory) and that analyzes the data to alert human operators to possible anomalies (see figure). The management of data in this application would involve two competing goals: One goal would be to adjust the volumes of data so as not to overwhelm the processing capabilities of the monitoring computer. This would be necessary to prevent delays in processing backlogged data. The other goal would be to maximize the useful information conveyed by those data that are admitted for processing, maintaining alertness to unusual events in the data, and focusing on particularly relevant tasks. In short, there would have to be a tradeoff between representativeness of the data and timeliness of the response computed from the data.

In this application and in other types of applications, DTE would entail four steps, of which the first two and part of the third would be completed during design of the system. In the first step, application-specific alternatives and the attributes or criteria that determine the values of parameters in the alternatives would be defined. Heuristics would be incorporated by specification of alternatives and rules about how to select them. Examples of alternatives might include elimination of channels not in a set called the "basic monitoring set," elimination of channels not in another set called the "minimal monitoring set," reducing the rate of sampling on a heuristically defined subset of channels, and reducing the rate of sampling on all channels.

Additional heuristics that show how to implement the alternatives would also be added in the second step. These heuristics would include refinements and exceptions to the rules introduced in the first step; for example, a channel in which the data indicated significant activity would not be deleted from the monitored set even when it was part of a predefined deletable subset.

In the third step, relative weights would be assigned to the attributes. Initial values and variance ranges would be defined at design time, and the values could be adjusted within the ranges during operation to accommodate changes (e.g., degradation of the equipment) in the monitored environment. The third step would also entail ranking each attribute in the context of each alternative. For example, an alternative that removed the largest number of channels that could supply data on anomalies of a given type would be ranked lower than another alternative that removed few-

er such channels.

In the fourth step, the single-attribute alternative rankings and attribute weights would be aggregated into an overall evaluation of alternatives. This evaluation, in combination with the application-specific heuristics, would enable the selection of the alternative of maximum value.

*This work was done by Ursula M. Schwuttke of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 56 on the TSP Request Card. NPO-18488*

# Scheme for Finite-Difference Computations of Waves

The discrete dispersion relation simplifies the generation of finite-difference algorithms.

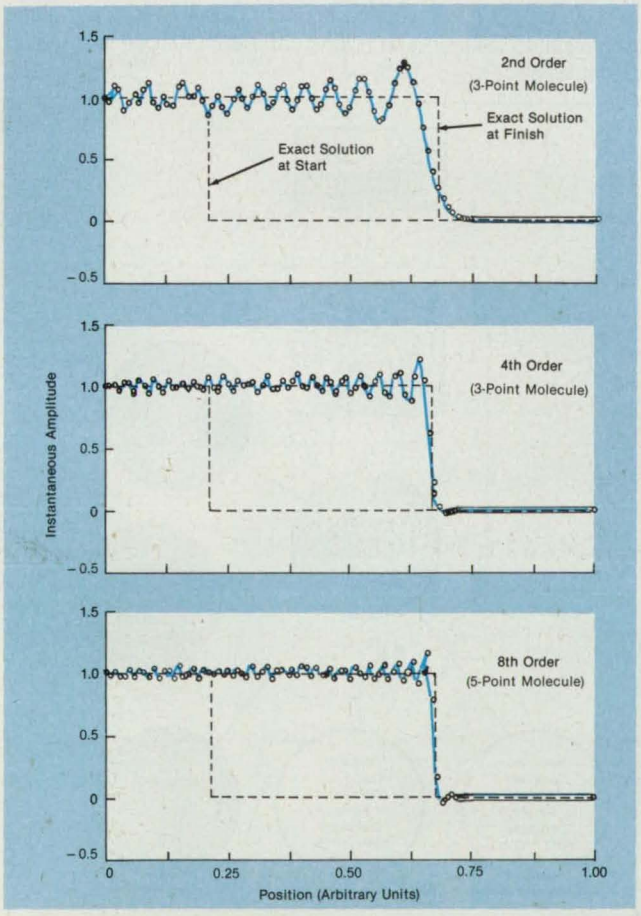
*Ames Research Center, Moffett Field, California*

Compact algorithms that generate and solve finite-difference approximations of the partial differential equations for the propagation of waves can be obtained by a new method. The method is based on the concept of the discrete dispersion relation, which is a finite-difference representation of the continuous (exact) dispersion relation and is developed from the continuous dispersion relation by examining the propagation of approximately locally plane waves through the chosen computational grid. The dispersion relation is used in wave propagation to relate frequency to wavelength and is a key measure of the wave fidelity.

Essential to even a brief summary of the method is the concept of the amplification factor. In this special context, "amplification factor" denotes the ratio between the complex amplitudes of the propagating wave at the same location at two instants separated by one computational increment of time. The spatial and temporal coupling expressed in the amplification factor is embedded in the dispersion relation of the wave. The amplification factor relates the transfer of information to the next time step, at a given location, to the scale(s) of the computational grid. It is used to transform the differential operator, in which the magnitude and phase information are embedded, into a finite-difference operator.

The discrete dispersion relation approximates the amplification factor. It has an exponential structure that suggests a computationally efficient splitting of the difference equation into convective and diffusive terms. Although the difference equations can also be derived by use of prior methods, the use of the discrete dispersion relation simplifies the derivation considerably. The accuracy of the difference equations is of the same order as that of the dispersion relation associated with the differential operator. If the coefficients are constant, then the accuracy is of high local order.

The method has been tested by using it to generate fourth-and eighth-order algorithms for a one-dimensional problem that involves three or five grid points (see figure). These algorithms are subject to the same restrictions that govern the use of dispersion relations in the construction of asymptotic expansions for nonlinear evolution equations. The fourth-order algorithm is exact at $Cn = 1$ and 2, while the eighth-order algorithm is exact at $Cn = 1, 2, 3,$ and 4 ("$Cn$" denotes the Courant number: $Cn = V\tau/h$, where $V =$ the speed of propagation at a given frequency, $\tau =$ the size




The **Propagation of a Unit-Step-Function Wave** was computed by second, fourth, and eighth-order algorithms derived via the discrete-dispersion-relation approach. The Courant number is 0.5, the wave started from x = 0.22, and the data points indicate the situation after propagation through 45 increments of space.

of the time step, and $h$ = the size of the space step). In problems dominated by phase accuracy, values of $Cn$ greater than about 2 (at fourth order) or 4 (at eighth order) cause unacceptable phase distortion. More-complex algorithms based on these concepts should be useful in the solution of problems like those of diffraction of acoustic waves, long-range propagation of waves through the atmosphere, the evolution of weakly nonlinear waves, or effects of propagating waves on the stabilities of flows.

*This work was done by Sanford Davis of* **Ames Research Center**. *Further information may be found in NASA TM-102215 [N90-16399], "A Space-Time Discretization Procedure for Wave Propagation Problems."*

*Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. ARC-12970*

# Front-End Processor for Metrology-Information System

Information for the management of a large calibration laboratory is displayed and modified systematically.

*John F. Kennedy Space Center, Florida*

The front-end processor for the NASA Metrology Information System (NMIS) is a real-time relational data-base computer system designed to distribute processing for the NMIS mainframe system or run as a stand-alone local-area-network data-base system. The NMIS-FEP system is being used in large calibration laboratories for work control and to maintain records of calibration, repair, costs, manpower usage, traceability, and other pertinent facts about the instruments supported by the laboratories. The NMIS-FEP system provides enhancements to the existing NASA Metrology Information System and can batch upload to minimize mainframe I/O at times of heavy usage.

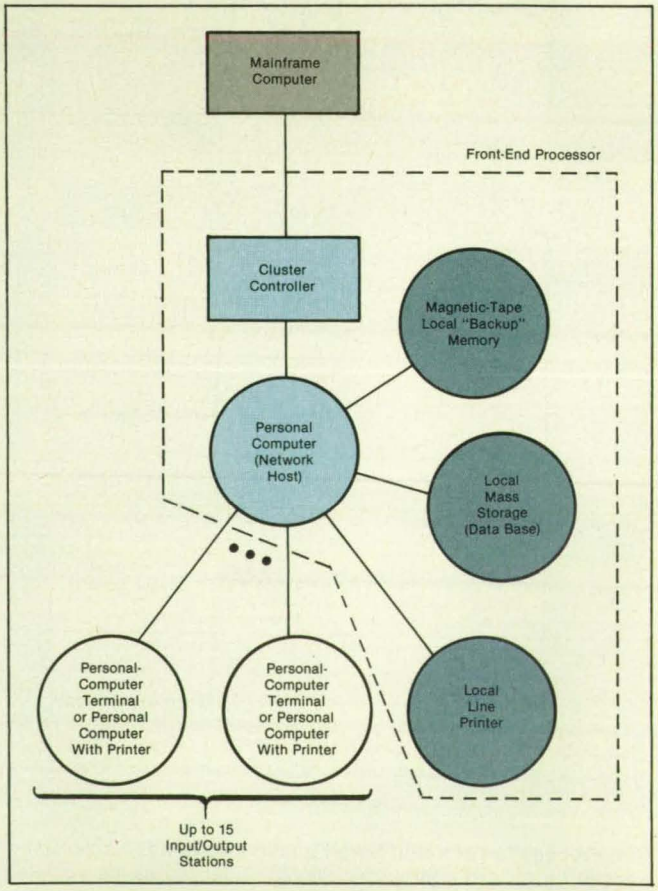
The front-end processor includes facilities to (1) update records, (2) generate standard and ad-hoc reports, (3) search rapidly for records on specific pieces of equipment by unique data elements such as serial numbers or job-order numbers, (4) interact with the mainframe NMIS System, and (5) maintain data integrity through the use of lookup tables. In addition, the front-end processor maintains an integrated data base on spare parts and can update costs on the records on the work control information system. The parts-information subsystem includes facilities for tracking the usage, cost, inventory control, updating, and editing of records.

The NMIS-FEP system provides point-and-shoot help windows on validated data elements via system lookup tables and provides for standardization of naming conventions. This help is provided when an incorrect or a blank entry is made. The user can also activate a field and menu-level help documentation specific to the context by pressing a function key.

The front-end processor can also operate as a stand alone single or multiuser data-base system and has been tested in the following environments: NOVELL, NTNX, UNIX i386 (under VPIX MS-DOS emulation), network-OS. The system acts as a cluster controller when interfaced via the SNA protocol or a token-ring node via the token-ring controller.

The system workstations can be personal computers or PC-terminals connected via coax, twisted pair, or RS-232. A personal computer acting as a server can support up to 100 workstations per node, and nodes can be interfaced to a global data base.






The **Front-End Processor** preprocesses transactions with the mainframe computer.

*This work was done by Walter S. Muse, Charles B. Sammet, and Michael G. Maxwell of Bionetics Corp. for* **Kennedy Space Center**. *For further information, Circle · 38 on the TSP Request Card. KSC-11470*

# Optimizing Reduced-Order Transfer Functions

Transfer-function approximations are made optimal in a special least-squares sense.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

An algorithm computes reduced-order rational-fraction approximates to single-input/single-output transfer functions. Approximations of this type are used because they reduce the amount of computation needed for such purposes as numerical simulation of dynamics and design of control subsystems. In the case of the present algorithm, the approximation is optimal in a special least-squares sense explained below.

Leaving out some details for the sake of brevity, the problem can be stated as follows: Let the response of the full-order system be represented by the $n$th-order transfer function

$$G(s) = \frac{N(s)}{D(s)} = \frac{a_0+a_1 s+a_2 s^2+\ldots+a_{n-1}s^{n-1}}{b_0+b_1 s+b_2 s^2+\ldots+b_{n-1}s^{n-1}+s^n}$$

where $s$ denotes the Laplace-transform complex frequency. Let the approximate transfer function that is sought be of $m$th order ($m<n$); namely,

$$\hat{G}(s) = \frac{\hat{N}(s)}{\hat{D}(s)} = \frac{\alpha_0+\alpha_1 s+\alpha_2 s^2+\ldots+\alpha_{m-1}s^{m-1}}{\beta_0+\beta_1 s+\beta_2 s^2+\ldots+\beta_{m-1}s^{m-1}+s^m}$$

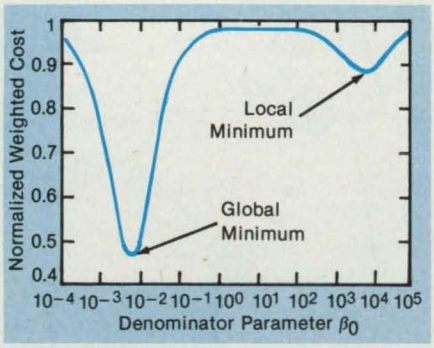
The error in the approximate transfer function is then given by $E(s) = \hat{G}(s) - G(s)$. The objective is to find values of the $\alpha$'s and $\beta$'s that minimize the frequency-domain error functional.

$$J \equiv J(\boldsymbol{\alpha},\boldsymbol{\beta}) = \int_{-\infty}^{+\infty} |E(j\omega)|^2 d\omega$$

By Parseval's theorem, this cost function is equivalent to the integral, over time, of the impulse-response error. By choosing $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ to minimize $J(\boldsymbol{\alpha}, \boldsymbol{\beta})$, one can make both the impulse and frequency responses of the reduced-order mathematical model approach those of the full-order model. More generally, one can use a frequency-weighted cost function

$$J_w = \int_{-\infty}^{+\infty} |E(j\omega)W(j\omega)|^2 d\omega$$

where $W(j\omega)$ is a weighting function chosen to shape the frequency response. For example, if one desires to enhance the accuracy of the approximate model in the low-frequency range and is less concerned about the response at other frequencies, one could select a $W(j\omega)$ that represents a low-pass filter.




This **Example of a Frequency-Weighted Cost Function** exhibits both a global minimum and another, local minimum. As in the case of other algorithms of the gradient-descent type, the algorithm described here can converge to a local or to a global minimum, depending on the initial choice of parameters.

Rigorous analysis shows that there exist parameter vectors $\boldsymbol{\alpha}^*$ and $\boldsymbol{\beta}^*$ for which $\hat{G}(s)$ is stable and is globally optimal in the sense that it minimizes the value of the cost function. The analysis also reveals that if the denominator coefficients $\boldsymbol{\beta}$ of the reduced-order model are specified, the optimal numerator coefficients $\boldsymbol{\alpha}$ are obtained from the solution of a weighted-least-squares problem in which the weighting matrix satisfies a Lyapunov equation. This observation leads to the development of the algorithm, which is an iterative gradient-descent algorithm that involves two main steps. In the first step, $\boldsymbol{\alpha}$ is updated by use of a weighted-least-squares subalgorithm. In the second step, the updated $\boldsymbol{\alpha}$ is used in a gradient-based, one-dimensional (line-search) subalgorithm to find the updated $\boldsymbol{\beta}$. Rigorous analysis also shows that the repetition of these two steps results in convergence to a stationary point of the cost function, though not necessarily to $(\boldsymbol{\alpha}^*, \boldsymbol{\beta}^*)$ (see figure).

*This work was done by John T. Spanos, Mark H. Milman, and D. Lewis Mingori of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 67 on the TSP Request Card. NPO-18358*

# Space-Time Neural Networks

Digital filters add the capability to process temporally varying data.

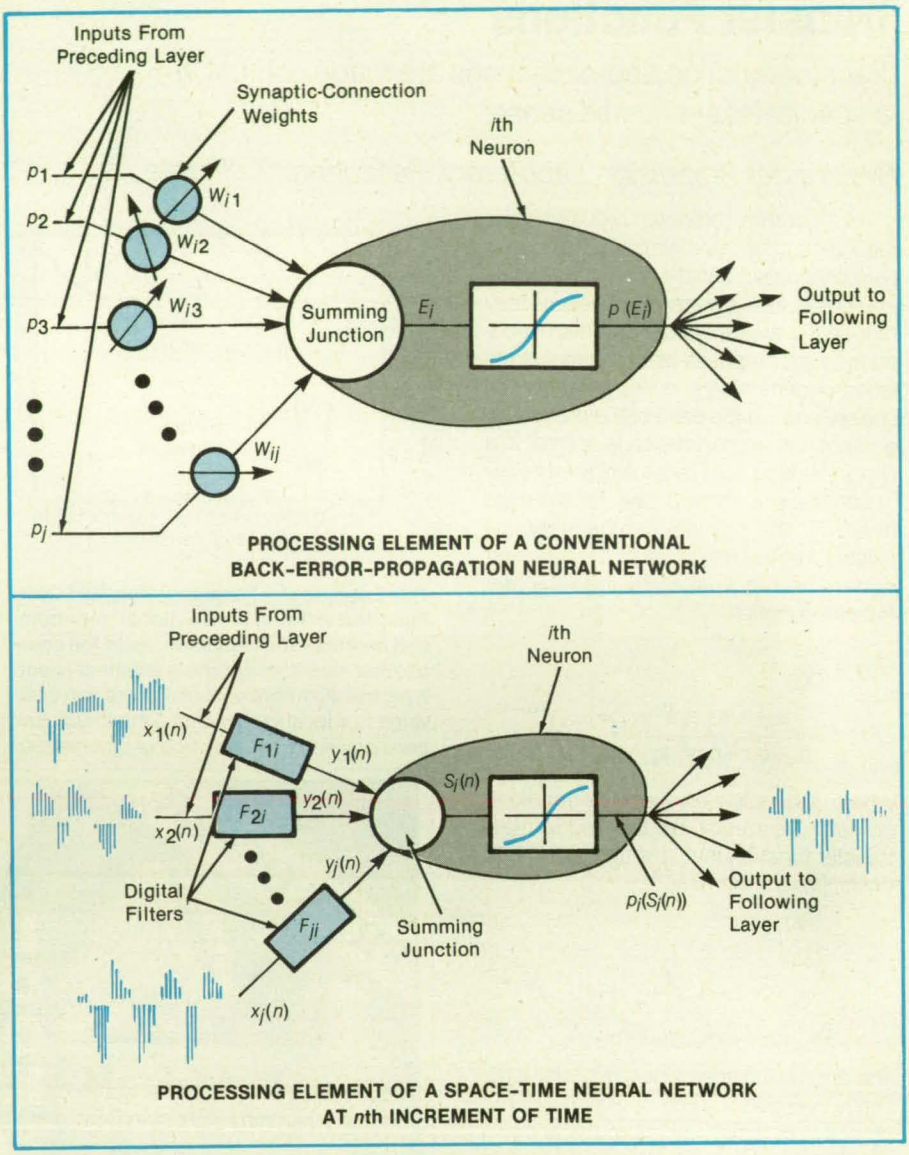
*Lyndon B. Johnson Space Center, Houston, Texas*

The concept of the space-time neural network is a generalization of the concept of the back-error-propagation network that adds the dimension of time. Although a back-error-propagation neural network can represent and process spatial information (e.g., it can recognize patterns), it cannot process temporally evolving spatial information (e.g., it cannot recognize an evolving pattern or predict how a pattern will change in the near future on the basis of the recent history of the pattern). The concept of the space-time neural network affords a distributed temporal memory that enables such a network to model complicated dynamical systems mathematically and to recognize temporally varying spatial patterns (or, equivalently, sequences of patterns).

A back-error-propagation neural network is trained by presenting it with a specified set of inputs that are meant to result in a specified set of outputs, then adjusting the weights of its synaptic connections in an iterative process until the errors (the differences between the actual and specified outputs) are acceptably small. The iterative process is called "back propagation" because in each cycle of the iteration, the connection weights are adjusted according to error gradients, proceeding backward through the network, one layer of neurons at a time, from the output layer toward the input layer. Once the network is trained, its connection weights are fixed, and it thereafter responds in the same way each time it is stimulated with the same inputs.

In a space-time neural network, the fixed (after training) synaptic-connection weights are replaced by the coefficients of adaptable digital filters (see figure). Each such filter records both the inputs it received from the associated neuron and the outputs it produced during previous increments of time; it sums the present input along with the recorded previous inputs and outputs, all weighted according to the filter coefficients. The sum is the output of the filter and is fed to the input-summing junction of a neuron in the next layer of the network. The back-error-propagation training algorithm must now be more complicated because it is necessary to adjust the filter coefficients that governed past histories to influence the present set of responses.

Some conceptual space-time neural networks have been tested by computer simulation. These include a network of one input neuron, six hidden neurons, and one output neuron working on a temporal version of the exclusive-OR problem; a network of two input neurons, eight hidden neurons, and eight output neurons working on the same problem; and a network of one input neuron, six hidden neurons, and one output neuron being trained to generate a chaotic (in the sense of pseudorandom) sequence of numbers. In all three test cases, the root-mean-square errors of the outputs decreased with the number of training passes, as one would expect.




**Digital Filters** in a space-time neural network replace the synaptic-connection weights of a conventional back-error-propagation neural network. Here, one neuron of a space-time neural network processes a set of input waveform sequences into a different output waveform sequence.

*This work was done by James A. Villarreal and Robert O. Shelton of* **Johnson Space Center.**

**For More Information Circle No. 42**

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 20]. Refer to MSC-21874.*

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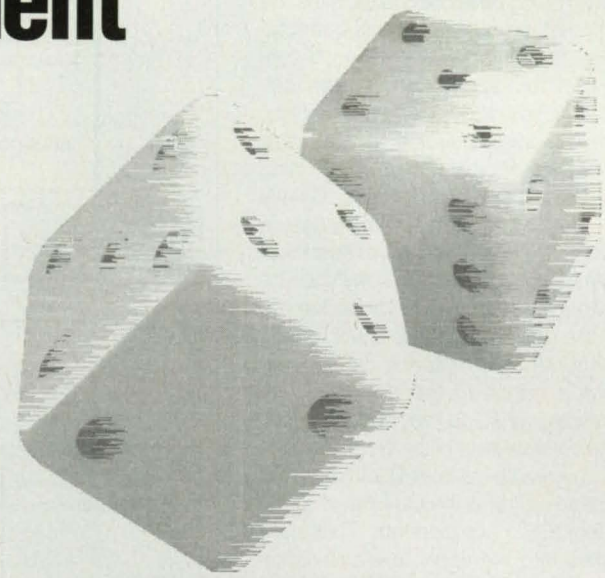

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**For More Information Circle No. 658**

# Automated Simulation for Analysis and Design

Expert-system software facilitates simulations of qualitative and quantitative aspects of behavior.

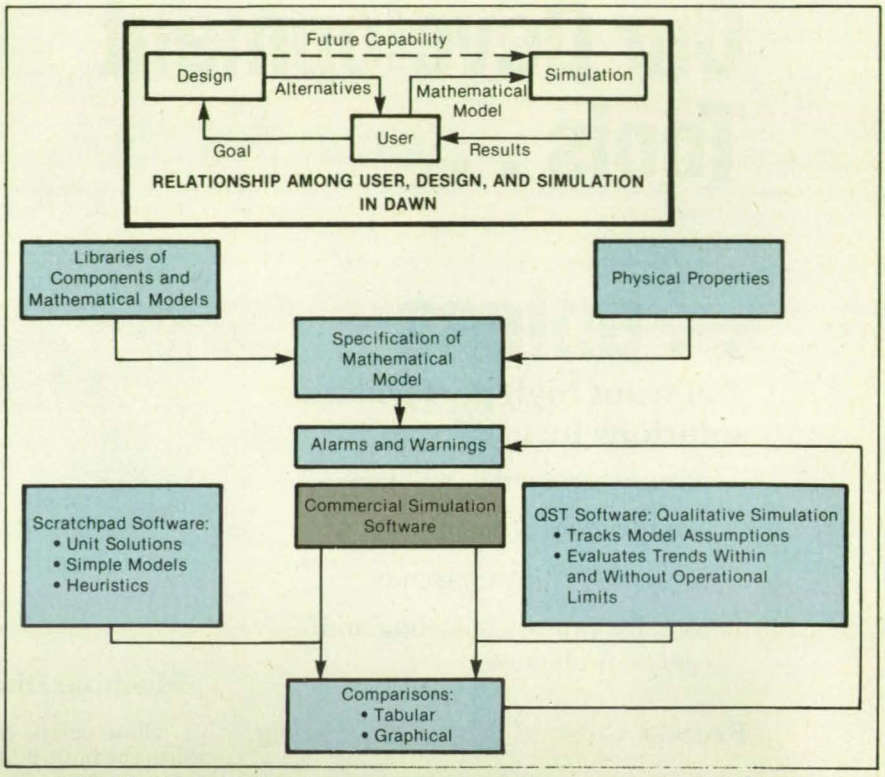
*Ames Research Center, Moffett Field, California*

The Design Assistant Workstation (DAWN) software is being developed to facilitate the simulation of the qualitative and quantitative aspects of the behavior of a life-support system in a spacecraft, a chemical-processing plant, the heating and cooling system of a large building, or any of a variety of systems that include interacting process streams and processes. DAWN will be used to analyze alternative design scenarios or specific designs of such systems. When fully developed, DAWN will be an expert system that will even automate part of the design analysis: it will reason independently by simulating design scenarios and return to the designer with overall evaluations and recommendations.

At the present state of development (see figure), the major parts of DAWN are the ScratchPad (SP) and the Qualitative Simulation Tool (QST) components. These are integrated with the applicable simulation software, which could be, for example, ASPEN+, a commercial program that simulates the behaviors of chemical-processing plants.

The SP component of DAWN incorporates expert knowledge that enables it to identify incorrect or misleading results caused by errors in mathematical models and by inherent limitations of the simulation methods being used. It provides libraries of mathematical models and capabilities for the validation of complicated models by comparison of their qualitative and quantitative results with the results of simpler models. When differences exceed thresholds specified by the user, alarms can be sounded.

The QST component of DAWN provides for the qualitative and semiquantitative modeling of processes in the system to be designed. It is based on the problem-solving strategies used by chemical engineers. If, for example, a query to a mathematical model can be answered qualitatively, QST makes an unambiguous prediction. If the qualitative simulation generates ambiguities, then QST resorts to increasingly specific and precise quantitative calculations to resolve them. In effect, it learns as it proceeds and makes it possible to change the description of the system being designed from one that is initially qualitative to one that is increasingly quantitative as information is added and processed.




**The DAWN Software System** incorporates engineering expertise to facilitate the simulation of behavior of a designed system and the analysis of alternative designs.

*This work was done by E. Cantwell of* **Ames Research Center**, *Tim Shenk and Peter Robinson of RECOM Software, and R. Upadhye of Lawrence Livermore National Laboratory. For further information, Circle 100 on the TSP Request Card.*
*ARC-12817*

# Analyzing Robotic Kinematics via Computed Simulations

Motions of conceptual manipulators in work cells are displayed on a computer video terminal.

*Goddard Space Flight Center, Greenbelt, Maryland*

A computing system assists in the evaluation of the kinematics of a conceptual robot. The system displays the positions and motions of the robotic manipulator within its work cell. It also displays interactions between the robotic manipulator and other objects.

The results of the simulation are displayed on a graphical computer workstation. The system includes both off-the-shelf software originally developed for the automotive industry and specially developed software. The software package functions at the following three levels:

1. A geometry modeler, which generates such basic parts as the links of the robot and objects to be manipulated;
2. A device builder, which puts the parts together to form a kinematic device; and
3. A work-cell modeler, which lays out the work cell and brings kinematic devices together to interact.

The simulation displays realistic images for analysis of collisions and the limits of motion of links. Equipment that is to be built as part of the continuing development task would enable the use of a hardware controller to control the motions of the simulated devices.

The simulation system has been used for other purposes as well. For example, it has been used to design a human-equivalent hand, to model the optical train in an infrared system, and to develop a graphical interface for a teleoperator simulation system.

*This work was done by Timothy M. Carnahan of* **Goddard Space Flight Center**. *For further information, Circle 99 on the TSP Request Card.*
*GSC-13433*

## Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

# More About Generating Three-Dimensional Grids About Anything

## Poisson's equation is used to fit grids to bodies of arbitrary shape.

A report presents additional details of the mathematical basis and potential applications of a method of generating three-dimensional grids fitted to bodies that can have arbitrary, complicated shapes. The grids are meant to be used in finite-difference or finite-volume computations of flows around the bodies. The grid-generation method involves numerical solutions of Poisson's equations; it has been implemented in the 3DGRAPE (Three-Dimensional Grids About Anything by Poisson's Equation) computer program, which was described in "Generating Three-Dimensional Grids About Anything" (ARC-12620), *NASA Tech Briefs*, Vol. 15, No. 6 (June 1991), page 58.

In this method, a grid is generated from the following Poisson elliptic partial differential equation:

$$\alpha_{11}\mathbf{r}_{\xi\xi}+\alpha_{22}\mathbf{r}_{\eta\eta}+\alpha_{33}\mathbf{r}_{\zeta\zeta}+2(\alpha_{12}\mathbf{r}_{\xi\eta}+\alpha_{13}\mathbf{r}_{\xi\zeta}+\alpha_{23}\mathbf{r}_{\eta\zeta}+)=-J^2(P\mathbf{r}_{\xi}+Q\mathbf{r}_{\eta}+R\mathbf{r}_{\zeta})$$

where $\mathbf{r}$ denotes the vector

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

of Cartesian coordinates of a grid point; $\xi$, $\eta$, and $\zeta$ denote the body-fitted curvilinear coordinates on which the grid is constructed,

$$\alpha_{ij}=\sum_{m=1}^{3}\gamma_{mi}\,\gamma_{mj}$$

$\gamma_{ij}$ is the $ij$th cofactor of the matrix

$$M=\begin{bmatrix} x_\xi & x_\eta & x_\zeta \\ y_\xi & y_\eta & y_\zeta \\ z_\xi & z_\eta & z_\zeta \end{bmatrix}$$

the Jacobian $J$ is the determinant of $M$, and each subscript denotes partial differentiation with respect to the denoted coordinate.

Typically, the flow field about a complicated body like an airplane is divided into zones to simplify the computations. A grid that can be mapped into a Cartesian-gridded computational cube is generated in each zone by solving the applicable Poisson's equation. The terms $P$, $Q$, and $R$ can be chosen at will. For the purposes of this method, they are chosen automatically by use of side-condition equations that minimize the skewness of the grid (that is, make it as nearly orthogonal as possible) and control the heights of grid cells near any or all faces of the zones. The side-condition equations are solved numerically, concurrently with the Poisson equation.

The resulting grid is smooth in the interior of each zone and across the boundaries with adjacent zones. One has the option of specifying or not specifying the shapes of the boundary surfaces between zones and the distribution of grid points on those surfaces. The numerical Poisson-equation-solution process can generate that information. This feature significantly reduces the amount of surface-fitting preparation required before the grid-generating method can be applied.

*This work was done by Reese L. Sorenson of* **Ames Research Center**. *Further information may be found in NASA TM-101018 [N88-28042], "Three-Dimensional Grids About Arbitrary Shapes by Poisson's Equation."*

*Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.*
*ARC-12276*

## Electrophoretic Process for Purifying Wastewater

Microbes, poisonous substances, and colloidal soil particles are removed by combinations of electric fields.

*Marshall Space Flight Center, Alabama*

An electrophoretic process removes pathogenic organisms, toxins, toxic metals, and colloidal soil particles from wastewater. It can be used to render domestic, industrial, and agricultural wastewater streams potable. The process could be especially useful in bioregenerative and other closed systems like those in space stations and submarines, in which water must be recycled.

In the process, free-fluid electrophoresis concentrates pathogens, particles, and ions electrically charged to the same polarity into one waste stream. If pathogens, particles, or ions of both electrical polarities are present, then they can be separated from the water and concentrated by application of electrical fields in such a configuration as to accommodate a balance of flow gradients and electrical forces. In a demonstration, the process has been used to remove *Escherichia coli* (a human pathogen), *Rhizobia* (a nitrogen-fixing bacterium in soil), and heavy metal from a waste stream by use of the ELSEP instrument.

The ELSEP instrument is a continuous-flow unit consisting of intercompartmental permeable membranes, which direct a gradient of crossflow of wastewater against an opposing electrical field. The method focuses charged particles into outlet streams according to their inherent surface charge. Because of the concentration of the pathogens, particles, or ions, it is possible to design systems for monitoring risks to humans by addition of existing on-line detection devices.

*This work was done by David W. Sammons, Garland E. Twitty, Rizwan Sharnez, and Ned B. Egen of the University of Arizona for* **Marshall Space Flight Center.** *No further documentation is available.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to*

*David W. Sammons, Ph.D.,*
*Veterinary Science Dept.*
*University of Arizona*
*Tucson, Arizona, 85721*

*Refer to MFS-26149, volume and number of this* NASA Tech Briefs *issue, and the page number.*

### Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

## How Humans Adapt to Heat

Responses during exertion and rest are described.

A report discusses the adaptive responses of humans to a hot environment. It notes that humans are unique among mammals for their ability to dissipate large amounts of heat by sweating, and that humans are essentially tropical animals: they have a much greater range of adaptive physiological responses to heat than they do to cold.

The report describes thermoregulation by integrated responses of the nervous system, the vascular/fluid/electrolyte system, and the endocrine system. It considers the disorders that result from failure of thermoregulation (heat stroke and heat hyperexia) and less serious heat stress (heat syncope, heat edema, heat exhaustion, and chronic heat fatigue).

The effects of exercise in a hot environment are analyzed: production of heat, thermal balance, and water and electrolyte balance. Short- and long-term adaptive responses to heat are described, including increased dissipation of heat by increased flow of blood near the body surface, increased sweating, and metabolic changes. The role of the hormone aldosterone in maintaining sodium content and raising extracellular fluid volume is briefly considered.

*This work was done by John E. Greenleaf of* **Ames Research Center** *and Hanna Kaciuba-Uscilko of the Polish Academy of Sciences. Further information may be found in NASA TM-101011 [N89-25558], "Acclimatization to Heat in Humans."*

*Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.*
*ARC-12596*

## Training for Estimation of Angles via Perspective Displays

People can learn to judge angles more accurately through video scenes.

Training can help people estimate angles more accurately from perspective pictures of three-dimensional scenes on two-dimensional displays, according to a report. The report is based on a study in which subjects were shown a scene containing a ground plane (represented by a perspective display of irregularly spaced parallel lines) and a reference cube and target cube floating above the ground plane. The scene was devised to represent scenes like those that occur in flight simulators and at robot-control stations, where the selection of trajectories, the perception of obstacles, and the manipulation of objects may be required.

The target cube appeared at various locations around the reference cube. Both cubes were at equal heights above the ground plane and tumbled slowly. Subjects were asked to estimate the angle between (1) the projection, onto the ground plane, of the line that connected the centers of the cubes and (2) the direction of the parallel lines in the ground plane.

A judgment dial was presented on the display screen of a workstation, and the subjects used a mouse to indicate on the dial their estimate of the angle. Each subject completed 10 runs with target directions presented randomly from a set of 54.

For the first three runs, there was no error display; the next target position was presented immediately after the judgment was signaled. The last seven runs were made with error displays: As soon as the subject signaled a judgment, an error cube appeared on the target circle in the direction indicated by the subject. If the subject had made an error, the error cube would be at an angle different from that of the target cube. The subject then used the mouse to move the error cube to the target cube, and the workstation displayed the magnitude of the error with a pointer on the judgment dial. Only after the subject had corrected the error by moving the error cube, and the workstation displayed the error pointer, did the system present the next target position.

The feedback from the error display was found to reduce, but not to eliminate, the errors. A lookup-table mathematical model of the errors was developed. In this model, the errors were attributed to overestimates of both the pitch and the yaw of the viewing direction used to produce the perspective projection. The model predicted the quantitative characteristics of the data somewhat better than previous models did.

A mathematical model of the learning mechanism that incorporates the lookup table was proposed. In this model, the subject updates his or her lookup table as a result of seeing the error in the current estimate of direction.

As a consequence of the training, users of perspective displays may be better able to interpret wide-angle displays used to increase the field of view, but which also introduce geometric distortion.

*This work was done by Gregory K. Tharp and Stephen R. Ellis of* **Ames Research Center**. *Further information may be found in NASA TM-102792 [N90-28329], "The Effects of Training on Errors of Perceived Direction in Perspective Displays."*

*Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.*
*ARC-12835*

## U.S. Biomedical Experiments in a Soviet Biosatellite

Final reports of 26 experiments are provided.

A NASA technical memorandum contains the final reports on a number of U.S. experiments, mainly biomedical experiments on rats, carried out aboard the Soviet Biosatellite Cosmos 1887. This satellite was launched on September 29, 1987, and recovered on October 12, 1987. More than 50 NASA-sponsored scientists from Ames Research Center and from universities throughout the United States were involved directly in 26 U.S./U.S.S.R. experiments.

Part 1 of the report describes the mission. Part 2 describes the U.S. flight and ground-support hardware. Part 3 provides a further overview of the mission and summaries of the experiments.

Part 4 contains the following detailed reports on the experiments:

- "Distribution and Biochemistry of Mineral and Matrix in the Femurs of Rats," by S. Arnaud et al.;
- "Biomedical, Biochemical and Morphological Alterations of Muscle and Dense, Fibrous Connective Tissues during 14 Days of Spaceflight," by A. Vailas et al.;
- "Gravity and Skeletal Growth," by E. Holton et al.;
- "Trace Element Balance in Rats during Spaceflight," by C. Cann et al.;
- "The Maturation of Bone and Dentin Matrices in Rats Flown on Cosmos 1887," by D. Simmons et al.;
- "Morphometric and EM Analyses of Tibial Epiphyseal Plates from Cosmos 1887 Rats," by J. Duke et al.;
- "Metabolic and Morphologic Properties of Muscle Fibers after Spaceflight," by R. Edgerton et al.;
- "Biochemical and Histochemical Observations of Vastus Medialis," by X. Musacchia et al.;
- "Morphological and Biochemical Investigation of Microgravity-Induced Nerve and Muscle Breakdown," by D. Riley et al.;
- "Effects of Zero Gravity on Myofibril Protein Content and Isomyosin Distribution in Rodent Skeletal Muscle," by K. Baldwin et al.;
- "Actin mRNA and Cytochrome c mRNA Concentration in the Triceps Brachia Muscle of Rats," by F. Booth et al.;
- "Morphometric Studies of Atrial Granules and Hepatocytes," by L. Kraft et al.;
- "Morphological and Biochemical Examination of Heart Tissue," by D. Philpott et al.;
- "Hepatic Function in Rats after Spaceflight," by A. Merrill, Jr., et al.;
- "Morphological Examination of Rat Testes," by D. Philpott et al.;
- "Structural Changes and Cell Turnover in the Rat's Small Intestine Induced by Spaceflight," by R. Phillips et al.;
- "Study of Muscarinic and GABA (Benzodiazepine) Receptors in the Sensory-Motor Cortex, Hippocampus and Spinal Cord," by N. Daunton et al.;
- "Pineal Physiology in Microgravity: Relation to Rat Gonadal Function," by D. Holley et al.;
- "The Effect of Spaceflight on Pituitary Oxytocin and Vasopressin Content of Rats," by L. Keil et al.;
- "Effect of Microgravity on 1) Metabolic Enzymes of Type 1 and Type 2 Muscle Fibers and on 2) Metabolic Enzymes, Neurotransmitter Amino Acids, and Neurotransmitter Associated Enzymes in Motor and Somatosensory Cerebral Cortex," by O. Lowry et al.;
- "Growth Hormone Regulation, Synthesis and Secretion in Microgravity," by R. Grindeland et al.;
- "Effect of Spaceflight on Levels and Function of Immune Cells," by A. Mandel et al.;
- "Radiation Dosimetry and Spectrometry," by E. Benton et al.; and
- "Analysis of Radiographs and Biosamples from Primate Studies," by C. Cann et al.

*This report was prepared by J. Connolly, R. Grindeland, and R. Ballard of* **Ames Research Center**. *Further information may be found in NASA TM-102254 [N90-26452], "Final Reports of the U.S. Experiments Flown on the Soviet Biosatellite Cosmos 1887."*

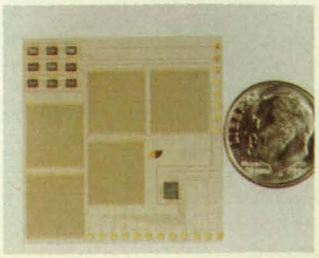
*Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.*
*ARC-12795*

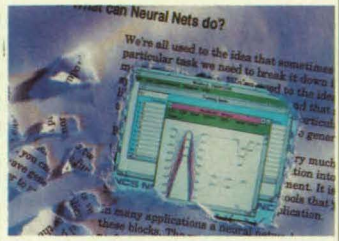
# New on the Market

Gould Inc., Valley View, OH, has introduced a **floppy disk storage unit** for use with its 1600 and 4070/80 families of digital storage oscilloscopes. The new DSU112 unit, which is available in both 3.5" and 5.25" versions, allows transfer of both waveform data and machine setups to and from the oscilloscope without the need for a computer. Fitted with its own GPIB interface, it requires no hardware modification or additional software.
**For More Information Circle No. 798**


Evans & Sutherland, Chicago, IL, has released version 4.0 of CDRS, a **computer-aided industrial design package** that now runs on IBM RISC 6000® workstations. Used to create accurate and realistic product models, CDRS automatically saves the designer's work in an electronic format that can be sent to engineering systems for analysis or to manufacturing machines for milling. New modeling features include automatic blending functions, a software-based renderer, and improved methods for creating offset surfaces and shut-lines.
**For More Information Circle No. 786**

The industry's first **superconducting multi-chip module** (MCM) has been developed by Superconductor Technologies Inc., Santa Barbara, CA. The MCM uses ten-micron-wide, high-temperature superconducting lines between complementary metal oxide (CMOS) circuitry. The circuitry consists of a series of nine CMOS digital inverters connected to form a ring oscillator and a counter. The hybrid circuit was tested at 77 Kelvin.
**For More Information Circle No. 800**





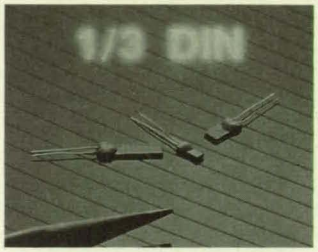

Neural Computer Sciences has announced NeuDesk, a low-cost, Windows-based **neural network package for PCs**. The software provides a means of evaluating this branch of artificial intelligence for specific business applications. An intuitive graphical user interface provides neural network access and a master drop-down menu leads the first-time user through the entire development process from inception to fully-trained, ready-to-use system.
**For More Information Circle No. 794**

TextMachine™, a **UNIX full-text distributed textual database product** designed for client/server architectures, is available from Alliance Technologies Inc., Austin, TX. TextMachine is a suite of tools and utilities that enables database application developers to build systems to collect, prepare, load, access, monitor, and manage very large distributed databases.
**For More Information Circle No. 766**

A new low-cost, two-wire **RTD temperature transmitter** from RdF Corp., Hudson, NH, incorporates separate linearity controls for accuracy to within ±0.1% of SPAN or ±0.1% °C, whichever is greater. The model 2900 transmitter offers a resolution of better than 0.05° C and a sensor upscale break indicator current limit of less than 30 mA.
**For More Information Circle No. 776**

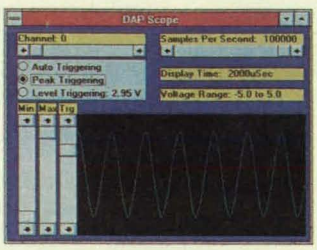
Aermet 100®, a patented **alloy** from Carpenter Technology Corp., Reading, PA, offers high strength and hardness as well as high fracture toughness and ductility for exceptional resistance to stress corrosion cracking and fatigue. The alloy is composed of nickel-cobalt steel strengthened with carbon, chromium, and molybdenum.
**For More Information Circle No. 788**

ACI Components, Laguna Hills, CA, has introduced a line of **precision thin film platinum RTD elements** featuring interchangeability of 1/3 the standard DIN specification, or ±0.04% at 0° C. Suitable for high-tolerance, high-quality sensing requirements, the new sensor offers excellent shock and vibration resistance in a small package envelope. Sensors are available in either 100 ohm or 1000 ohm values.
**For More Information Circle No. 762**

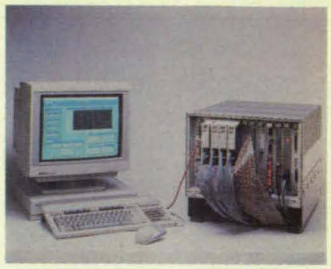



The industry's fastest **notebook computer** has been introduced by Quantitative Technology Corp., Beaverton, OR. Dubbed the QTC3500, it features an 80486DX microprocessor and operates at 33 MHz. The computer comes with an internal 120-210 MB hard disk drive and a 3.5" 1.44 MB floppy disk drive, as well as 4 MB of built-in RAM, expandable to 16 MB. Weighing just seven pounds, the QTC3500 has a built-in backlit monitor that can display VGA, EGA, and MGA graphics, two serial ports, and a parallel port.
**For More Information Circle No. 778**

Laser Design Inc., Minneapolis, MN, has introduced the SURVEYOR model 500, the newest model in a line of **3D laser digitizing systems**. This entry-level, high-speed, 3D laser digitizer has been developed for fast turn-around prototyping, reverse engineering, CNC duplicating, stereolithography, and inspection applications. The system offers resolution of ±.001" in standard work envelopes of 6" x 12" x 6", four axes of motion for access to all surfaces, and speeds of 100" per minute.
**For More Information Circle No. 792**

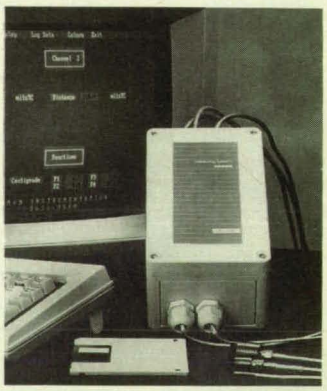



A **Windows toolkit** developed by Microstar Laboratories, Bellevue, WA, enables Windows applications to communicate with a data acquisition processor. On-board intelligence permits users to measure and control fast-changing events in real time, continuously acquiring data at rates up to 235,000 samples per second.
**For More Information Circle No. 784**



The HP75000 model HD2000 **data acquisition system** from Hewlett Packard Co., Palo Alto, CA, lets users measure and characterize physical parameters of electromechanical devices and structures with fast, continuous, mixed measurement data throughput to disk (200,000 readings per second). The high-performance, VXI-based system comprises a C-size VXI cardcage, an embedded computer, measurement cards, and software programming tools. Advantages include easier systems integration and faster programming, command execution, and data conversion.
**For More Information Circle No. 780**

Kaman Instrumentation, Colorado Springs, CO, has unveiled the EASI-9500™, a **noncontacting, microcontroller-based position measuring system** capable of single- or dual-channel operation. It accurately measures position, gap, thickness, alignment, diameter, run-out, and vibration of conductive objects, with an accuracy of 0.01%/°C over a 60° C range. "Smart" sensing allows the user to determine how the measurement information from each channel will be processed.
**For More Information Circle No. 790**



Chorus Systems Inc., Beaverton, OR, and Archipel have announced the first **transputer-based distributed UNIX system**. Built on Chorus microkernel technology, Archipel's VOLVOX-TS family brings parallel processing power to the UNIX Open Systems environment. Integrating the Chorus operating system, CHORUS/MiX, into Archipel's VOLVOX MIMD (Multiple Instruction Multiple Data) machines provides the execution power of a supercomputer at a fraction of the cost, according to the manufacturers.
**For More Information Circle No. 774**

# New on the Market

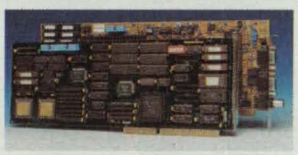
The fast and accurate SPC1 **electropneumatic pressure control** from Buzmatics Inc., Indianapolis, IN, helps increase calibration and testing consistency and improve overall production quality, according to the manufacturer. The valves are designed to operate for millions of cycles and never require calibration, minimizing down time. They also can take an electronic command signal and control air pressure while simultaneously providing an electronic feedback signal of actual pneumatic pressure.
**For More Information Circle No. 782**

The SurePoint™ **laser probe** from TSI Inc., St. Paul, MN, precisely measures the velocity of any flowing medium—gas, liquid, or solid—with a noncontacting technique that eliminates flow disturbance. Based on laser Doppler velocimetry techniques, the compact unit combines a laser source, transmitting optics, receiving optics, and a photodetector. Suited for "point and shoot" diagnostics, it also can be paired with an automated signal processor.
**For More Information Circle No. 772**

A novel **pocket PC** developed by Zeos International Ltd., St. Paul, MN, weighs just 1.3 pounds and delivers ten hours of battery life under continuous use. Measuring approximately 9-1/2" x 4-1/2" x 1", the system comes with eight software programs, including spreadsheet, word processing, database, file transfer, and communications packages. The $595 model features 1 MB of RAM and 1.5 MB of ROM. Two additional built-in PCMCIA slots enable the system to accept memory cards.
**For More Information Circle No. 768**

Lightwave Communications Inc., Milford, CT, has introduced a **fiber optic video transmission system for computer workstations** that allows 1280 x 1024 pixel images to be sent up to 500 feet from a processor to a high-resolution display. Called the VDE/200 system, it can send super VGA signals (1024 x 768 pixels) up to 3000 feet. Since it does not require access to the workstation's operating software, the unit is platform-independent.
**For More Information Circle No. 760**

Molectron Detector Inc., Portland, OR, has announced two **pulsed Nd:YAG probes** that measure average power of pulse energies to 5J/cm² at 1.06 μm and 0.53 μm via a proprietary volume-absorbing optical material. The models PM10V1 and PM30V1 measure up to 10 w and 30 w, respectively. Each probe is available with calibration at 266, 355, 532, or 1060 nm, and offers better than 1% linearity, spectral range of 0.19 to 6.0 μm, and a 19 nm clear aperture.
**For More Information Circle No. 770**



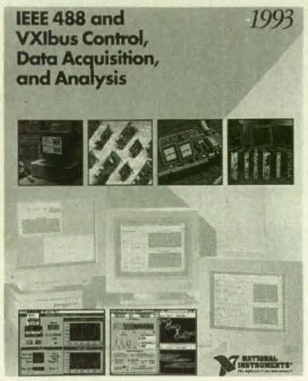
The EAGLE, a low-cost, real-time **image processing board** for the IBM PC/AT with built-in VGA display and frame grabber, has been introduced by Univision Technologies Inc., Burlington, MA. Multiple 640 x 480 x 8 bit images can be transferred, processed in real time at 30 frames per second, and then displayed at 60 Hz noninterlaced on a standard VGA monitor. The entire system occupies just two PC/AT card slots, including the VGA output.
**For More Information Circle No. 796**

The new **fast file access option** on Contemporary Cybernetics Group's CY-8500 8mm **tape drive** permits UNIX users access to any file on a 25 GB tape in under two minutes, reducing labor and search times as well as wear and tear on the drive. The option is available only on the CY-8500, which can store between 5 GB and 25 GB on one tape at speeds of up to 90 MB per minute.
**For More Information Circle No. 764**

# New Literature

Deltron Inc., North Wales, PA, has published a 40-page catalog of **switching power supplies**, open frame linears, stand-alone modules, accessories, and options. New products include a stand-alone power factor corrector and the model PF-VME auto-ranging power fail monitor. The catalog highlights the modular open frame family of Moduflex switchers, offering a wide variety of standard and custom configurations.
**For More Information Circle No. 706**

The 1993 catalog from National Instruments, Austin, TX, describes **measurement and instrumentation products** and provides updates on data acquisition, instrument control, and data analysis solutions. The 544-page publication describes software and hardware for integration into systems based on PC/XT/AT, PS/2, EISA, Macintosh, Sun, Hewlett-Packard, DEC, and other platforms. Applications include laboratory and factory automation, automated test, process monitoring and control, and motion control.
**For More Information Circle No. 708**

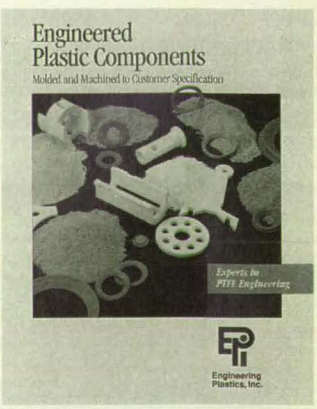



A four-page brochure from Alcoa Wire, Rod, & Bar Division, Massena, NY, highlights Deltalloy™ 4032, a highly wear-resistant, cold-finished **aluminum alloy** for a range of industrial uses. Deltalloy 4032 offers excellent durability and surface finish; good machinability, weldability, and drilling characteristics; and a low coefficient of thermal expansion. It requires no hard coat anodizing, which reduces production costs by as much as 50%.
**For More Information Circle No. 714**

An 11-page **short form** catalog offered by Sharp Electronics Corp., Camas, WA, provides data on the company's character LCD modules, medium- and large-size graphic LCD modules, color TFT-LCD modules, electroluminescent display products, inverters, and backlights. A large-size LCD technical reference guide is included.
**For More Information Circle No. 704**


A bulletin from Technipower Inc., Danbury, CT, describes its line of **variable autotransformers, automatic voltage regulators, and VIP power line conditioners**. Tutorials are provided on such topics as how to select a variable autotransformer based on the line and load characteristics of a particular application and the effects of temperature and duty cycle.
**For More Information Circle No. 710**

The ISPA Co., Baltimore, MD, has issued its *Guide to Ten Critical Coating Questions for Project Managers.* The booklet addresses cost-effectiveness of Teflon® fluoro-polymer coating, the advantages of coatings over sheet linings and glasteel, compliance with FDA regulations, resistance to corrosive environments, coating irregular shapes, and determining the proper coating system for various applications.
**For More Information Circle No. 702**




Engineering Plastics Inc., Westboro, MA, has released a brochure describing its capabilities in **manufacturing parts from Teflon®, PTFE, and other engineering-grade plastics** for industrial, electronics, and other high-tech applications. Featured products include seals, diaphragms, machined parts, wafer and mask carriers, Teflon tanks, bearings for handling high loads, and brake pads.
**For More Information Circle No. 712**

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Electrical engineer, scientist, Ph.D, with more than ten years successful research and development in universities and research centers. Expertise in channel coding, error correcting codes, and information theory. Experience in digital signal (speech and image) processing, filters design, fast Fourier transforms, and medical imaging. Proficient programming in C and FORTRAN for DOS and UNIX environments. Seeking a position requiring research, development, and teaching.
**Box Number 2**

Electronic engineer with RF/Analog design experience to 1 GHz; RF systems design using Motorola 56001 and TRW TMC2310 FFT processors; and analog/digital automotive test equipment design using Intel 80186 processor and 82526 CAN with paged non-volatile memory. Also switching/linear power supply design.
**Box Number 3**

25+ years experience as an IND/MFG engineer with extensive exposure as a consultant in varied industrial climates. Employed for last 12 years by Textron Defense Systems (formerly AVCO) as an engineer in strategic and tactical DOD system acquisition. Will consider full-time or contract work.
**Box Number 4**

Six-year McDonnell Douglas software/systems engineer. Embry-Riddle Aeronautical University BSCS/engineer. Seeking computer/engineering/automation work in sunbelt area. French/Russian language ability, non-smoker. Phone 904-760-9362. Write: Techie, P.O. Box 7114, Daytona Beach, FL 32116-7114.
**Box Number 5**

Ph.D in physics with skills in simulation, image processing, robotics, and multidisciplinary research. As architect conceived new systems, performed studies, wrote requirements, analyzed trade-offs and life cycle costs, specified designs, selected equipment, wrote software, trained personnel, supervised engineers, and performed validation, acceptance and test procedures for integration and delivery.
**Box Number 6**

Technology manager/metallurgist. 30 years experience in the processing—especially the powder metallurgy—of titanium, aluminides, superalloys, and niobium for gas turbine engine and missile applications. Designed, equipped, staffed (and motivated) a pilot plant demonstrating the manufacturing effectiveness of a new way of making monolithic thin-wall (<.5mm) hollow engine components.
**Box Number 7**

Propose and develop physical models to explain data and guide experimental programs in diverse fields within energy, environment, and defense: combustion, emissions control, spray atomization, materials processing, high velocity impact, fragmentation, acoustics, laser effects, rarefied gas dynamics and transport in porous media. Will relocate. Ph.D in aerospace engineering, Cornell.
**Box Number 8**

Position wanted in system analysis and software development. Ph.D in engineering with major in astrodynamics and minors in control theory and dynamics. MSEE with emphasis on computers, control theory, and communication theory. 24 years experience.
**Box Number 9**

Engineering/physics BS, MS (one year grad work in solid state physics). Three years manufacturing automation experience, three years teaching/training at high school/college level. 12 years experience in process measurement and control in chemical/petrochemical plants, environmental remediation. Computer and programmable controller proficient.
**Box Number 10**

Recent graduate from Oregon Institute of Technology with BS in laser optical engineering technology. Optics: fibers, Fourier, IR/UV, geo/physical optics, detection, testing. Electronics: op-amps, analog/digital, high-power electronics. Some work experience, including a summer in Saudi Arabia. R&D and/or field work preferred.
**Box Number 11**

In-depth experience in data analysis, graphics, programming/documentation and project control. Results oriented with balanced approach to requirements, budgets and time constraints. Skilled with IBM compatibles and Macintosh PCs.
**Box Number 12**

Physicist with expertise in lasers, optics, accelerator system, free electron lasers, and x-ray and particle diagnostics. Extensive experience in scientific and artificial intelligence computer programming. Both project management and university teaching experience. Seeks challenging research or academic position.
**Box Number 13**

Project and business management, contract administration, and project cost analysis. BS in industrial engineering, graduate work in business. Self-starter, team-motivator, adept at fulfilling detailed requirements. Proposed, negotiated, interpreted, and supervised defense contracts. Managed administrative personnel. Led team of technical and production personnel. Computer-friendly: Lotus 1-2-3, Symphony, Fortran, WP. DOD and DOE clearances. TQM-trained.
**Box Number 14**

Senior hardware systems engineer with 30+ years experience with commercial and government systems. Experience in secure network gateway; 80X86, 680X0 families; micro-controllers; process control; FFT processor; network interfaces and protocols; assembly languages; C course; and A/D monitor and recorder. BSEE and MS in engineering management. Multibus; PC Bus; CAD. Paul Zepf, 11439 Osoyoos Place, San Diego, CA 92126, (619) 271-5261.
**Box Number 15**

Mechanical engineer with MSME and MBA. More than 25 years experience in electronic packaging, heat transfer, space/optical systems, fluid flow, and management. Outstanding performance supported by references. Seeking a full-time or a contract position in either engineering or management. New England or New York area.
**Box Number 16**

BSME with five years experience designing and testing crew station and exterior lighting, NVG and commercial, concept to production. CAD literate. Machine shop and plastic molding. Excellent hands-on mechanical ability and problem solving. Creative, strong work ethic. Will make substantial contribution to your success.
**Box Number 17**

Broad experience in heat transfer and fluid dynamics analysis. SINDA computer program to make 3D transient temperature predictions. Missile aerodynamic synthesis using DATCOM and CAMS programs, as well as empirical methods. Extensive wind tunnel and free jet testing and data analysis, including plume simulations and flow interactions. Available for consulting/part-time work.
**Box Number 18**

MSEE (emphasis: control system theory) and BSEE with seventeen years diverse experience in mathematical modeling, simulation, and analysis of dynamical systems. Extensive experience in technical proposal preparation. Supervisory experience including technicians and analysis/product development groups. Excellent customer interface skills including design reviews and technical marketing consultations.
**Box Number 19**

Systems engineer (BSEE) interested in parallel distributed processing/knowledge engineering hybrid technologies. Computer sciences background including Master's level courses in neural networks, computability, and AI. Heavy usage of C and Fortran in science and engineering. Strong on communications standards and information systems architectures. Prefer travel and/or contract programming.
**Box Number 20**

Mechanical engineer (MSME) and scientific programmer with 5+ years experience modeling, simulating, and analyzing thermal and fluid phenomenon. Proficient on various computer platforms (VAX, DOS, UNIX) and languages (Fortran, C) and experienced in using many different software modeling programs. Good communicator and team player. Seeking position in an R&D commercial environment.
**Box Number 21**

Registered professional manufacturing engineer with more than 20 years experience in the manufacturing/industrial engineering field: project/program management, automated material handling, information systems development and bar code standards. Instrumental in developing and implementing configuration management database program. Listed in Who's Who.
**Box Number 22**

Quality assurance manager seeks position with a company desiring to improve its performance, i.e., quality & productivity. Excellent related experience including quality program audits, proposals, plans, procedures, TQM, SPC, SQA, QE, MRB, configuration management and ISO programs for aircraft & aerospace products & services. Call (818) 365-2200; if no answer, please leave message.
**Box Number 23**

MBA Stanford Business School, BS in metallurgical engineering, 20 years experience in semiconductor operations and semiconductor equipment marketing. Seeks marketing or operations management position. Led organizations of 220 and managed budgets of $12M. Product development, sales management in Europe, Japan, US. Photomasking, CAD, IC test and wafer sort.
**Box Number 24**

Ph.D electrical engineer/physicist; flexible on location and salary; willing to travel. 34 years professional experience in proposal writing, project management, computers, electromagnetics, lasers, optics, rocket fuel systems, ordnance, safety-arming switches, plasma and atomic physics, reactor design, and shock waves. Albert G. Engelhardt, 549 Bryce Ave., Los Alamos, N.M. 87544, Tel: (505) 672-9246, Fax: -1435.
**Box Number 25**

BSEE looking for control systems design position. Experience includes computer interfacing process controls with analog and digital designs as well as writing and testing control programs for batch and continuous processes. Enjoy working in Basic, C, ladder, graphics and leading PLCs. Also prefer total system design, implementation, and project management responsibility.
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Senior level multimedia systems developer, strategic analyst & planner. Member ANSI and ISO experts groups on compression of digital images, motion-video and audio; and electronic still picture imaging. Experience developing MPEG-Video chip and MPEG-Audio software. Prior work on Apollo lunar program, military AI machine, and FAA fault-tolerant computing system. Alfred Riccomi (214) 644-8875.
**Box Number 28**

Extensive experience as lead systems/dynamics engineer. Background includes derivation of requirements; trade studies; technical analysis including component and system FEM development, modal synthesis, and transient load cycle analysis for both Shuttle and ELVs; dynamic testing including modal and random vibration tests; model correlation; and customer presentations. EBI/SBI file number available.
**Box Number 29**

Stereoscopic & virtual reality technology specialist. Over 25 years experience in the design, construction, and implementation of state-of-the-art stereoscopic imaging and display systems. High-resolution stereoscopic film, HDTV, computer graphics, robot vision, and printed image systems for industry, education, medical, and aerospace applications. Develop methodology for data enhancement and compression, noise reduction, photointerpretation, and reduction of ambiguity through application of stereoscopic difference information technology.
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Seeking very senior employment/significant contract opportunity—EVP/chief scientist/principal investigator. Dozen government research contracts over decade, neural networks, speech recognition, free-form text/image management, signal processing. No geographic restrictions, prefer Rocky Mountains/Northwest. P. Nicholas Lawrence, Ph.D, P.O. Box 460441, San Antonio, TX 78246-0441, (512) 349-5666, nlawrenc@ringer.cs.utsa.edu.
**Box Number 31**

Background in simultaneous engineering processes, preference for medical device manufacturing or biological process equipment design and installation. Extensive patent and aerospace experience can aid in search for new consumer products to fit aerospace company conversion. Skills include: CAD (AutoCAD, Intergraph, Generic); plastics part and mold design; process chemical equipment and piping; automated production systems; product development process.
**Box Number 32**

Electrical engineer with BSEET and 5+ years of experience seeks factory automation/process control position. Developed ladder logic software for A-B PLC-5, Gould, TI-405 controllers. Experienced in designing ATE and stepper motor control circuits. Developed software for ATE. Willing to relocate.
**Box Number 33**

MSE in engineering mechanics. Extensive experience in FEA, mainframe and PC (Nastran, Cosmos, Algor). Experience in vibration analysis, modal analysis, and mechanical design. Background in aerospace and industrial manufacturing. Consulting experience.
**Box Number 34**

BSEE looking for entry level position involving processing or design of ICs. Experience in research and manufacturing. Primary experience is with SOI and power MOSFETs. Wrote a paper concerning defects in ZMR SOI MOSFET devices. Knowledge of control systems and optoelectronics. Excellent communication skills and technical writing abilities.
**Box Number 35**

Ph.D in mechanical engineering with 10+ years management experience and a strong technical background in design and analysis. Produced many novel solutions to equipment design resulting in 15 US patents. Recognized for providing sound technical input and recommendations based on extensive engineering experience and strong analytical skills.
**Box Number 36**

Ph.D in electrical engineering seeks interdisciplinary research position in electrical/biomedical engineering. Interest in physiological electrostimulation (pacemakers, TENS), physiological instrumentation, and human tactile information display for telerobotics of virtual environments. Skills in experiment design and analysis, analog circuits, troubleshooting. PC and Mac. Industrial experience. Kurt Kaczmarek, (608) 276-9577.
**Box Number 37**

BSME, MS in aeronautical structures. 22 years experience including positions as Stress Analyst; Composites Specialist; Chief Design Engineer; and Deptartment Manager (materials R&D). Experience includes university liaison, extensive proposal preparation (incl. govt.), project planning, and budgetary control. Considered creative, with well-developed leadership skills. Division closure requires a new opportunity.
**Box Number 38**

Specification/technical writer or editor. 9+ years experience writing, editing, proofreading, maintaining engineering specifications (MIL-STD-490) and other technical documents. Familiarity with MIL-STD-480 configuration management practices. Mac experience: MS Word, PageMaker, MacDraw, Excel, and Aldus Freehand. Will relocate to northwest, southwest, southeast US.
**Box Number 39**

Science policy and strategic marketing professional. Experience in business strategy, public policy analysis, and international competitiveness. Background in electronics, information services, and telecommunications. MBA, Chicago; MA in technology and human affairs, Washington University. Interests in technology commercialization and research management. Former positions at Motorola, GTE, IIT Research Institute, and National Academy of Sciences.
**Box Number 40**

Dedicated, motivated Ph.D with 20+ years commercial, teaching, and government experience. Telecommunications systems engineering, design, analysis, and simulation. RF/microwave devices, antennas, phased arrays, low noise, high power, and broadband. 300 Hz to 50+ GHz, laser links. Ground, ship, aircraft, and satellite. Loral, Lockheed, TRW. Publications, excellent presentations. Top clearances. Relocate at own expense.
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Looking for an entry-level position in computational science and engineering. Two years of part-time work experience in numerical analysis, non-parametric signal processing, and computational fluid dynamics. Proficient in Fortran, Word Perfect, TEX, the UNIX system, the grid generation codes EAGLE and GENIE, and various database software packages. US citizen.
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BS in chemistry, MS in polymeric materials engineering with background in materials and process engineering and manufacturing engineering. Broad-based experience in all phases of plastics and polymers. Diverse work in plastics processing: injection molding and thermoforming, thermoset processing such as fiberglass (composite) processing, encapsulation/conformal coating/painting, bonding, transfer/compression molding.
**Box Number 43**

BSME with broad engineering experience including design, manufacture, and quality control in manufacturing environments. Worked for DOD contractors supplying mechanical equipment to US Army and Navy. Administrative and supervisory experience; extensive work with military specifications. Tasks included design and analysis of valve equipment for commercial nuclear power plants and quality assurance of power plant equipment (commercial, ASME Code, and DOD quality assurance systems).
**Box Number 44**

BSME, MBA, with eight years experience in consumer product development: product liability, fire cause and origin, and product safety. Design of sheet metal and injection molded parts. UL and other agency testing of appliances. Certified through ASQC in quality and reliability engineering, and quality auditing. Associate degree in electronics technology.
**Box Number 45**

December 1992 MS in human factors specializing in human-machine systems. Interests include user interface design, task analysis, and operator's information processing and design making capabilities. Have C/C++/Lisp programming experience. Seeking position involving user interface design for complex systems. Salary negotiable. Chicago preferred but willing to relocate.
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Software engineer experienced in software requirements, design and coding, integration and testing. Software development per DOD-STD-2167A and familiar with all related DIDS. Languages: FORTRAN 77, C, JOVIAL, GOAL, and Assembly. Computers: VAX, Z8000 Micro, IBM PC, CDC Cyber and 1750. 10+ years experience in systems/software.
**Box Number 48**

Ph.D research manager with extensive experience in applied plasma and nuclear physics, and excellent technical marketing, presentation, and leadership skills. Successfully developed and marketed numerous R&D programs for small business and would like to do the same for your company. Contact: Dr. F.J. Mayer, 1417 Dicken Drive, Ann Arbor, MI 48103.
**Box Number 49**

GIS specialist/geographer. Experience: ARC/INFO, AutoCAD, MapInfo, IDRISI, Surfer DBase, MBase, Fortran, C, ADA, Pascal, SAS UNIX, DOS, IBM PS/2 Model 70. Innovative problem solver, excellent communication skills. MA 12/92, BA 6/90. Available immediately and willing to relocate. Resume upon request. Contact Mike, tel. (607) 648-9619.
**Box Number 50**

Highly skilled systems engineer eagerly seeks employment in any of the following areas: avionics systems integration into reconnaissance aircraft; supercomputer detailed design; digital computer field support; proposal and spec writing; all aspects of VLSI CMOS chip and board design; personal computer network integration (Ethernet, ARCnet); and marketing support (analysis of technical issues). Contact: Thomas M. Demaree, 640 Glencoe St. NE, Fridley, MN 55432. Tel: (612) 786-8112.
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Rocket scientist/mechanical engineer with over 25 years of experience; flexible; can adjust quickly to a broad range of engineering and manufacturing jobs. Can generate projects (pilot, prototype, etc.) from concept to production start-up at any level of state-of-the-art methods and technologies. Looking for a position in R&D, CAD/CAM, and manufacturing as well as management.
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Syracuse honor graduate seeking ME position in design or manufacturing in Portland, OR area. Several years of hands-on experience repairing heavy equipment and as service manager. Excellent mechanical aptitude, capable writer, good employee. CAD and ANSYS experience. References. Contact: Chandler Yarnall, 3605 NE Bryce, Portland, OR 97212. Tel: (503) 335-0476.
**Box Number 53**

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To obtain resumes corresponding to the above **Positions Wanted Ads**, fill out this form and mail to: *NASA Tech Briefs*, 41 East 42nd St., New York, NY 10017. ATTN: Jim Westbrook, or call 1-800-944-NASA and ask for Jim Westbrook.

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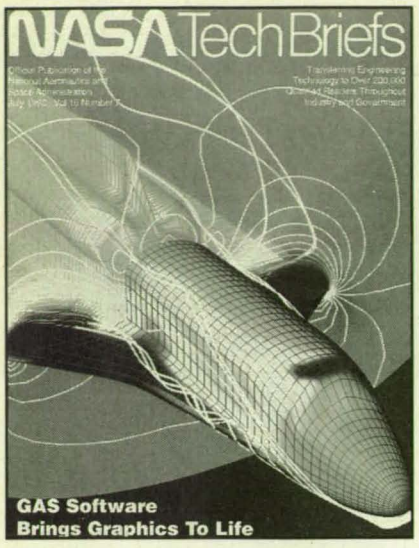


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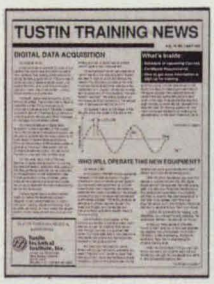


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**For More Information Circle Action No. 301**


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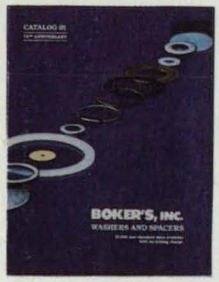


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**National Instruments**

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20-page illustrated guide covers the Teclab line of technical work stations and laboratory systems furniture. Included are stations of different lengths, combined with a choice of cabinets, shelves, parts drawers, partitions, and other accessories. Catalog has dimensions, shows arrangements, describes work surfaces, and has a color selection guide. Call 800-832-5227, Fax: 616-372-6116. Address is Box 1165, Kalamazoo, MI 49005.

**Kalamazoo Technical Furniture, Inc.**

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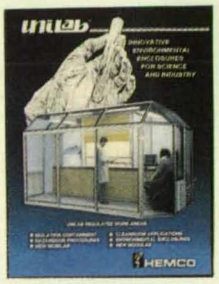
## ELECTRIC LINEAR ACTUATORS

Three series of electric rodless and standard cylinders and controls are covered in this 136-page catalog. It provides performance data, comparisons, dimensions, and accessories. Additional sections provide sizing and selection design considerations and applications.

**Industrial Devices Corp.**

**For More Information Circle Action No. 312**

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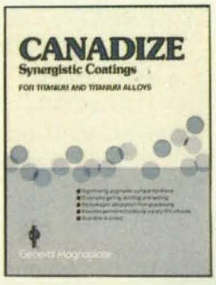


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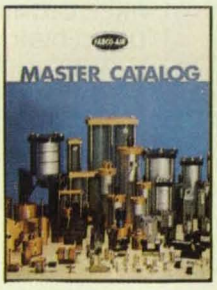


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**Fabco-Air, Inc.**

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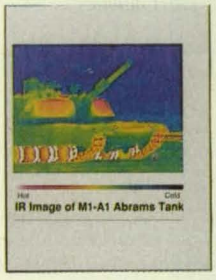


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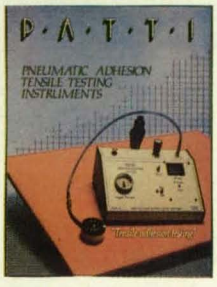


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**For More Information Circle Action No. 323**


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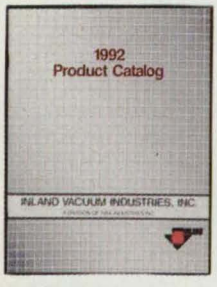
**Carr Lane Mfg.**

**For More Information Circle Action No. 324**




## VACUUM PUMP FLUIDS

Inland Vacuum's '92 catalog features their complete line of vacuum pump fluids, greases, and preventative maintenance products. A complete vacuum fluids chart is enclosed for easy reference. Reclamation service for expensive fluids and oils is described for environmental and cost savings measures.

**Inland Vacuum Industries, Inc.**

**For More Information Circle Action No. 325**


## FREE CATALOG: OFF-THE-SHELF OPTICS

Free 130-page product catalog from Rolyn, world's largest supplier of "off-the-shelf" optics. 24-hour delivery of simple or compound lenses, filters, prisms, mirrors, beamsplitters, reticles, objectives, eyepieces plus thousands of other stock items. Rolyn also supplies custom products and coatings in prototype or production quantities.

**Rolyn Optics Co.**

**For More Information Circle Action No. 326**

## PASSIVE FIBER OPTIC COMPONENTS

This 20-page, color catalog describes Gould's entire line of singlemode and multimode couplers, wavelength division multiplexers and cable assemblies. Product information includes specifications, package dimensions, connectorization options and glossary of terms. Applications include telecommunication and CATV systems, instrumentation and sensors.

**Gould, Inc.**

**For More Information Circle Action No. 327**


## FastCAD-POWERPACKED WORKHORSE FOR CAD

FastCAD works for you! Save time and money with FastCAD's blazing speed and dynamic user interface. If you are serious about generating fast, detailed CAD drawings, call 1-800-874-4028 for a free hands-on demo disk.

**Evolution Computing**

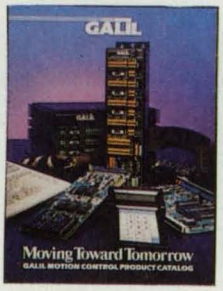
**For More Information Circle Action No. 328**


## HUNTER MINI-PLATING PENS

Low-cost disposable applicators permit instantaneous selection from a variety of plating possibilities without preparation of solutions. Specially formulated plating compounds can be used anywhere; prototype development work, electronic instrument repair, contact repair, etc. Pens available: copper, tin, zinc, nickel, black nickel, silver, chrome-color, rhodium, palladium and gold (24, 18, and 14K). Phone: 908-526-8440, Fax: 908-526-8348.

**Hunter Products, Inc.**

**For More Information Circle Action No. 329**




## PROGRAMMABLE MOTION CONTROLLERS

16-page catalog describes full line of servo motion controllers. Includes box-level industrial controllers; multi-axis plug-in bords; and low-cost, single-axis motion cards. PC/XT/AT, STD, VME and RS 232 interfaces available. Linear and circular interpolation, gearing, programmable I/O, and memory. Also power amplifiers, servo motors and support software.

**Galil Motion Control, Inc.**

**For More Information Circle Action No. 330**


## MOTION CONTROL PRODUCT GUIDE

Aerotech's 216-page Motion Control Product Guide describes their extensive lines of motor-driven linear and rotary positioning stages; DYNACRON microstepping translators; stepping motors and drives; servo motors, amplifiers and drives; and brushless drives. Also described is Aerotech's UNIDEX™ motion controller line. A special four-page insert describing the capabilities of Aerotech's Systems Engineering Division is included.

**For More Information Circle Action No. 331**


## EMCOR's QUICK-SHIP ENCLOSURES

Modular enclosures are shipped in five or 10 working days, depending on color preference. This 24-page full-color catalog features all accessory options and more. Phone: 507-289-3371. Address: 1600 NW 4th Avenue, Rochester, MN 55901.

**Emcor Products**

**For More Information Circle Action No. 332**


## ADVANCED COMPOSITE WORKSHOPS

The brochure describes seven different "hands-on" workshops in advanced composite materials technology covering fabrication, tooling, repair, engineering design for specialized repairs, and ultrasonic inspection of composites. Emphasis is on prepreg carbon and aramid fiber material and processes, utilizing vacuum bagging and high-temperature curing methods. Workshops vary from 3 to 8 days in length. Phone: 1-800-638-8441.

**Abaris Training Resources, Inc.**

**For More Information Circle Action No. 333**


## DSP SYSTEMS PRODUCT CATALOG

Pentek's free 1992 catalog describes a variety of VMEbus and Multibus baseboards and mezzanine expansion modules. Hardware offerings include TMS320C40, 'C30, 'C25 and DSP32C processors and co-processors, A/D's and D/A's, digital I/O, SCSI interfaces, precision clock generators, TI/CEPT telecom interfaces, and VMEbus adapters for SUN and PC-AT. Software offerings included. Phone: 201-767-7100, Fax: 201-767-3994.

**Pentek, Inc.**

**For More Information Circle Action No. 334**


## LOW-COST DIGITAL VIBRATION CONTROLLERS

Easy to use Expansion Card & Software from VTS convert your 386 or 486 personal computer to a powerful Digital Sine or Random Vibration Controller. Frequency ranges—Random 500, 1000, or 2000 Hz, Sine 5 to 6250 Hz. Many other unique features. Free demo disk available (learn to operate Controller in less than one hour).

**Vibration Test Systems**

**For More Information Circle Action No. 335**


## FIBER/LITE™

Aerospace fasteners made of composite for use with composite. These fasteners exhibit high tensile, shear and fatigue strength. They have low creep, water absorption and thermal expansion, can be made signature free and are half the weight of aluminum while exhibiting equivalent strength. They include gang channels, rivets, inserts, nuts and pins in orthogonal weave or chop fiber forms. Phone: 714-898-4377, Fax: 714-891-7467

**Tiodize Co., Inc.**

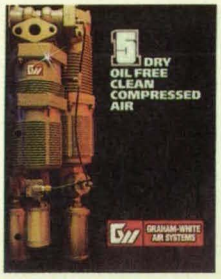
**For More Information Circle Action No. 336**


## FIBER OPTIC DISPLACEMENT SENSORS

Sensors for precision dynamic measurements on non-conductive and conductive materials. Non-contact sensors described in catalog include reflectance dependent and reflectance compensated models. Applications include dimensional measurements and motion analysis of vibrating or rotating targets. From $595. Phone: 410-757-4404, Fax: 410-757-8138. Address: Box 359, Arnold, MD 21012.

**Philtec, Inc.**

**For More Information Circle Action No. 337**




## '5-IN-1' AIR SYSTEMS

The Graham-White 5-in-1 air systems extend a money back performance guarantee for dry, oil free, clean compressed air. The water, oil varnish and particle contaminants are removed from the compressed air without the hassle of refrigeration and CFC emissions. Phone: 703-387-5600, Fax: 703-387-5639. Address: 1242 Colorado Street, Salem, VA 24153-1099.

**Graham-White Manufacturing Co.**

**For More Information Circle Action No. 338**


## FIBER INSULATED HEATERS

Manufacturers of fiber insulated heaters to 1200 °C (2190 °F) in standard flat heater panels, full and half round cylinders and also custom shapes and sizes. Complete range of accessories are available. Address: 110 North Main St., Florida, NY 10921-0458.

**Zircar Products, Inc.**

**For More Information Circle Action No. 339**


## PROGRAM-MABLE POSITION CONTROL

A complete 416-page engineer's guide with specifications, dimensions, and performance data presents brushless servos, microstepping motor systems, indexers, linear motors and absolute encoders.

**Compumotor Div., Parker Hannifin Corp.**

**For More Information Circle Action No. 340**


## POSITIONING SYSTEMS AND COMPONENTS

Daedal's 200-page catalog provides specifications for cross roller and ball slides; center and side drive cross roller tables; closed and open frame motorized tables; rail tables; manual and motorized rotary tables; digital micrometer stages; single- and multi-axis motion controllers; half step, microstepping and servo motor drives; and optical positioners and hardware.

**Daedal Div.,Parker Hannifin Corp.**

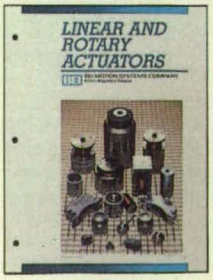
**For More Information Circle Action No. 341**


## INDUSTRIAL & CLEAN ROOM ROBOTS

Stäubli Unimation supplies robots into a wide range of applications including assembly, material handling, semiconductor clean room, machine loading, inspection, arc welding, nuclear materials handling, education, entertainment and many others. Four and six axis robots to meet your needs. Phone: 201-584-4441, Fax: 201-584-4302.

**Stäubli Unimation, Inc.**

**For More Information Circle Action No. 342**




## ACTUATOR BROCHURE

This guide makes linear and rotary voice coil selection easy. Features motor and winding constants for BEI's comprehensive, high-performance actuator line. Detailed dimensional information includes size, mounting, configuration and lead termination. Available in standard, modified or custom designs.

**BEI Motion Systems Co., Kimco Magnetics Div.**

**For More Information Circle Action No. 343**


## NEW CONCEPT IN WAVEFORM DISPLAY

Show waveforms on any VGA monitor without the complications of a computer! Use Modular Instruments' new Scroller-Scope, a compact, stand-alone, easy-to-operate unit. Capture waveforms in real time, without the fade-out common to slow sweep speeds of a conventional oscilloscope. Use it as a digital storage oscilloscope for negative-time triggering. See milliseconds to hours of data from a maximum of eight channels on a single screen.

**Modular Instruments**

**For More Information Circle Action No. 344**


## ELECTRONIC HARDWARE CATALOG

Broadest selection of hardware for electronic assemblies. 300-page free catalog includes a full range of standoffs, captive screws and nuts, chassis fasteners, handles, ferrules, spacers and washers. Special sections—new/unusual products, metric information, and Mil-plating specifications. Full inventory, fast turnaround, samples.

**Accurate Screw Machine Co.**

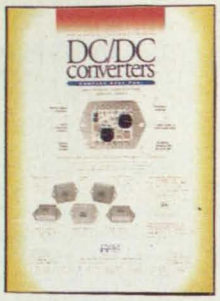
**For More Information Circle Action No. 345**


## COMPUTER CONTROLLED CCD VIDEO CAMERA

Literature features the new C72 Video Camera System that links to your imaging computer. Provides time saving operations such as digital control for gain and black levels, bandwidth and enhancement control, gamma and a switchable test signal for quick contrast setup of any monitor or frame grabber. Phone: 219-872-5514, Fax: 219-872-5559. Address 701 N. Roeske Ave., Michigan City, IN 46360.

**Dage-MTI, Inc.**

**For More Information Circle Action No. 346**

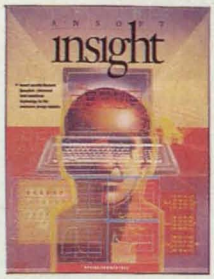



## HIGH-RELIABILITY HYBRID DC/DC CONVERTERS

Four-page product selector guide contains complete product and packaging specs for the Apex line of 20W and 10W hirel, hybrid dc/dc converters. Guide details Apex's new hybrid manufacturing process, lower per unit costs and advanced packaging. Phone: 602-690-8600, Fax: 602-888-3329.

**Apex Microtechnology Corp.**

**For More Information Circle Action No. 347**




## ELECTRO-MAGNETICS

Ansoft's Maxwell Field Simulators provide a dedicated tool for electromechanical, high-voltage, and magnetic applications. Links to AutoCAD, Pro-Enginer, SDRC, and others. Find out why more companies use Ansoft's tools for electromagnetics. Phone: 412-261-3200, Fax: 412-471-9427. Address: Four Station Square, Suite 660, Pittsburgh, PA 15219.

**Ansoft Corporation**

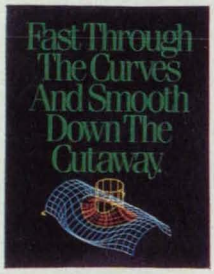
**For More Information Circle Action No. 348**

## WALL-SIZED DISPLAY FOR COMMAND & CONTROL

Media Wall™ transforms an array of monitors or projectors into a giant computer screen for "wall-sized" displays of text, graphics, animation and scanned photographs. A direct digital interface to a computer produces images of startling clarity, making Media Wall the ideal system for command and control applications and photo analysis.

**RGB Spectrum**

**For More Information Circle Action No. 349**




## SURFACE MACHINING SYSTEM FOR DOS

Call 800-488-3615 for literature and a working 3-disk demo of SURFCAM, and easy-to-learn, sculptured surface machining system for DOS and Windows. Complete 3D design and editing and fast 32-bit background processing at low PC-CAM prices. Phone: 818-361-5605, Fax: 818-361-1919. Address: 421 Park Ave., San Fernando, CA 91340.

**Surfware, Inc.**

**For More Information Circle Action No. 350**


## LOW-COST, PC-COMPATIBLE DATA LOGGER

Puts eight thermocouple channels on monitor, printer, or disk for $279 complete. Specifically for laboratory and industrial temperature monitoring. Avoids complex set-up or installation and is functioning within minutes. RS-232 interface powers converter and eliminates sensor wires at computer. QuickBasic®MS source code and compiled program provided. 16-channel and linear sensor options.

**DCC Corp.**

**For More Information Circle Action No. 351**


## TABLECURVE 3.1—AUTOMATED CURVE FITTING SOFTWARE

Find the best equation easily and fast! 3,318 built-in equations are fit automatically to your XY data. Equations are ranked; review curve-fits graphically. Full numeric summary presented. Output hardcopy, complete programming code or various file formats. Phone: 800-874-1888, Fax: 415-453-7769. Address 2591 Kerner Blvd., San Rafael, CA 94901.

**Jandel Scientific**

**For More Information Circle Action No. 352**


## RECIRCULATING CHILLERS

72-page catalog features a complete line of recirculating chillers for cooling water cooled equipment. These chillers offer steady cooling with heat load removal up to 75 kilowatts, spanning temperature ranges of -5 °C to +35 °C. Chillers feature LED display, operating status gauges, and easy access to internal components. Also available are Constant Temperature Bath/Circulators, Benchtop Personal Freezers and Immersion Coolers. Call toll-free at 800-258-0830.

**NESLAB Instruments, Inc.**

**For More Information Circle Action No. 353**


## IR IMAGING SYSTEMS

Inframetrics manufactures IR imaging temperature-measurement systems that are in use worldwide in nondestructive testing, predictive maintenance, research and development, electronics design and manufacturing, medical, and law-enforcement environments. The broad range of Inframetrics IR systems, software, capabilities and applications is described in this new, full-color brochure.

**Inframetrics**

**For More Information Circle Action No. 354**


## B92 CATALOG RELEASE

The latest catalog from W.M. Berg, Inc., coincides with Berg's silver anniversary. Founded in 1967, Berg has grown to become a recognized industrial leader of miniature precision mechanical components. A significant amount of new items are added as well as expanding previous product lines. Featuring 60,000 standard components, 80% of which we are able to ship from stock within 24 hours. Available in metric version too; M92.

**Winifred M. Berg, Inc.**

**For More Information Circle Action No. 355**


## HIGH VISIBILITY MULTI-USE DISPLAYS

Signalex high contrast seven segment and alphanumeric displays provide maximum visibility indoors or outdoors. 1-1/2" to 24" heights for visibility up to 1,000 feet. Electromagnetic bi-stable operation uses power only during display change and maintains indication even during power failure. Applications include instrumentation, timing/metering displays, industrial controls, etc. Phone: 516-666-8000, Fax: 516-666-8039.

**The Staver Co., Inc.**

**For More Information Circle Action No. 356**


## SPECIALTY GAS, EQUIPMENT CATALOG

Spectra Gases' 1993 specialty gases and equipment catalog is now available. This catalog contains specifications on pure gases, gas mixtures, gas handling systems and related equipment, halogen scruber systems, ion-laser tube repair, and isotopic gases and related equipment.

**Spectra Gases**

**For More Information Circle Action No. 357**


## P-CAD

The P-CAD family of products from CADAM Inc., offer powerful productivity solutions for designing state-of-the-art printed circuit boards. Master Designer, Premier PCB, and Associate Designer are comprehensive, integrated PCB design tools supporting schematics through routing and manufacturing.

**CADAM, Inc.**

**For More Information Circle Action No. 358**


## 500 WAYS TO USE MASS FLOW

Brochure includes free wall chart that lists 500 ways to use K-Flow® Coriolis mass flow meters for hundreds of fluids—for acids, oils, resins, water, emulsions, and more! Measure mass flow, density, temperature, net flow, concentration, %'s solids/liquids, and specific gravity; and with accuracies to better than 0.25% for flows from a few cc's to 2,000 lbs/min. K-Flow®'s software rich flow computer even runs many control devices by itself, saving time and money. Call today for complete info! 800-82K-FLOW.

**For More Information Circle Action No. 359**


## GRASEBY IR SYSTEMS

Manufacturer of digital blackbody sources (from .25" to 12" x 12"), off-axis collimators, spectral radiometers and variable speed modulators. Graseby IR Systems is also producing low-noise preamplifiers for photovoltaic, photoconductive and lead salt detectors. For more information call 407-823-8745, Fax: 407-273-9046. Address: 12151 Research Parkway, Orlando, FL 32826.

**Graseby IR Systems**

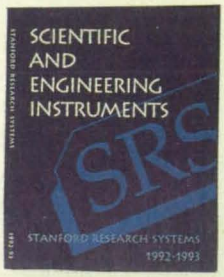
**For More Information Circle Action No. 362**


## 1,000-PAGE INSTRUMENT CATALOG

The 1992 Davis Test Measurement & Control Catalog features over 300 new pages with state-of-the-art instrumentation. Air velocity, pressure, temperature, electrical, sound, light, gas, tachometry, and much more. The Davis catalog represents over 250 manufacturers, including Fluke, Alnor, Horiba, Orion, Eaton, Promac, Ametek, Dwyer, Honeywell, Quest, and Ashcroft. Request your copy. Phone: 800-368-2516, Fax: 410-358-0252.

**Davis Instrument Mfg. Co., Inc.**

**For More Information Circle Action No. 363**




## SRS CATALOG

Stanford Research System's 1992-93 Catalog contains full information on its scientific and engineering instruments, featuring the latest function generator, current preamplifier and digital lock-in amplifier products. The 160 page catalog contains complete specifications, technical discussions and application notes on SRS's products, and is a useful reference for a wide range of test and measurement applications. Phone: 408-744-9040. Address: 1290 D Reamwood Ave., Sunnyvale, CA 94089.

**Stanford Research System**

**For More Information Circle Action No. 364**

## MAGNET CHARGING/ CONDITIONING

Walker Scientific has engineered a full line of magnet charging and conditioning equipment which encompasses DC, half-cycle and capacitive discharge technologies to handle all magnetic materials including the neodymium-iron-boron (Nd-Fe-B) magnets. When coupled with Finite-Element-Analysis engineering for fixture design a complete engineered system emerges. Phone: 201-402-7862, Fax: 201-402-7863.

**Walker Scientific Inc.**

**For More Information Circle Action No. 365**


## CUSTOM BUILT EQUIPMENT

Full color catalog describes custom and standard built process equipment, for the opto-electronics and semiconductor industries, R&D or production oriented equipment. The catalog covers liquid phase epitaxial (LPE) systems, chemical vapor deposition: CVD & LPCVD systems, metal organic chemical vapor deposition: MOCVD systems, and tube sealing vacuum stations for ampule sealing. Phone: 818-718-8955, Fax: 818-718-0359.

**General Air Corporation**

**For More Information Circle Action No. 367**


## NOISE CONTROL PRODUCTS

New color brochure describes SONEX and SONEX I sound-absorbing materials with patented shapes that control noise better than standard acoustical treatments. Brochure explains basic noise control techniques and presents many forms, sizes, and colors of SONEX products for industrial, office and OEM noise control. Brochure shows applications and includes information on acoustical performance.

**Illbruck, Inc.**

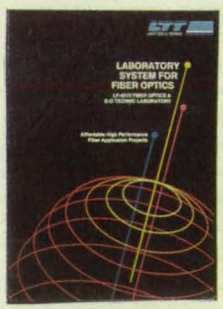
**For More Information Circle Action No. 368**


## INTERAVIA SPACE DIRECTORY 1992-93

Designed for the space professionals. Interavia Space Directory includes national, cooperative and military programs, detailed photographs and diagrams of launchers, communications equipment, navigation and the latest developments in space. ISD includes the addresses and phone numbers of the top aerospace contractors.

**Jane's Information Group, Inc.**

**For More Information Circle Action No. 369**




## FIBER OPTICS EDUCATION KIT

Laser Tools and Technics LF-4310 system is an integrated FO-communications and electro-optics instruction kit. System integration provides higher performance and more experiments at a lower price. The 20 labs cover basic to advanced fiber principles, from cutting fiber to use of lock-in amplifiers and fiber interferometers.

**Saguaro Scientific Corporation**

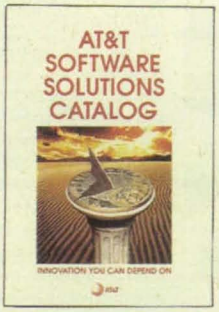
**For More Information Circle Action No. 370**


## THERMOSTATS & CONTROLS

Four-color, 16-page designers' catalog covers comprehensive line of industrial thermostats with set-points from 35-600°F. Included are ½-and ¾-inch snap-action models, probe types, expansion styles, and high temperature thermostats. Detailed electrical and mechanical specs are given.

**Selco Products Co.**

**For More Information Circle Action No. 372**




## SOFTWARE SOLUTIONS CATALOG

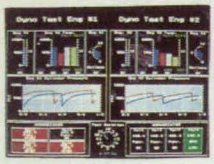
New catalog features 38 innovative software packages developed and tested within AT&T. Applications include communications, operations and network management software, development and performance tools, math/stat packages, and more, for various platforms/systems. Ideal source for remarketers and end users.

**AT&T Software Solutions Group**

**For More Information Circle Action No. 374**

## 201,000 Reasons Why Your Ad Belongs Here

*NASA Tech Briefs'* Literature Spotlight section offers a low-cost way to reach over 201,000 industry and government LEADERS with your advertising message. These are technology managers, design engineers, and scientists with tremendous buying power. The **December 1992** issue is your next opportunity to use this high-impact sales tool. For more information or to reserve space in Literature Spotlight, contact your *NASA Tech Briefs* sales representative (listed on page 10 in this issue) or call Joseph Pramberger at (800) 944-NASA.



### SCIENTIFIC AND ENGINEERING SOFTWARE TOOLS

A demo-disk and catalog is available for the Quinn Curtis line of scientific and engineering software tools for C and Pascal programmers. Scientific charting, numerical methods, real-time graphics, measurement and control, and huge virtual array libraries are discussed in detailed data sheets.

**Quinn-Curtis**

**For More Information Circle Action No. 375**


### FIBER OPTIC VIDEO TRANSMISSION SYSTEMS FOR C31 & BROADCAST

Data sheets detail systems design specs for DYNAIR's video, audio, data and high resolution RGB graphics transmission systems. Maximum distance 15 km with multimode fiber. Phone: 1-800-854-2831 for systems design support.

**DYNAIR Electronics, Inc.**

**For More Information Circle Action No. 376**


### AUTOMATED FILTER WHEEL ASSEMBLIES

Brochure describes remote/computer controlled filter wheel assemblies for true color imaging, luminance, and photometry with monochrome cameras. Obtain RGB images with cooled slow-scan CCD's. Six or eight positions, accepting 1" or 2" square or round filters. Rugged construction supports a variety of instruments. Also available: image analysis software and photometry filter sets designed to match the response of specific detectors.

**Saguaro Scientific Corporation**

**For More Information Circle Action No. 377**


### OPTICAL REFERENCE CATALOG

Edmund Scientific's free 204-page, full-color annual reference catalog features one of the largest selections of precision optics, and optical instruments, plus a complete line of components and accessories for both large volume OEM users as well as smaller research facilities and optical laboratories. It contains over 8,000 hard-to-find items.

**Edmund Scientific**

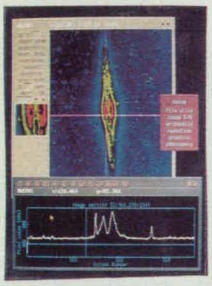
**For More Information Circle Action No. 378**


### TEFLON SEAL DESIGN MANUAL

Describes seals made from PTFE AND PTFE based compounds for rotating, reciprocating, and static applications. Lists seals in inch, metric, and custom sizes. Coverage explains seal types, unique spring loading operation, material compositions, correct selection, and typical applications. Sections detail surface finishes and installation procedures.

**Bal Seal Engineering Co., Inc.**

**For More Information Circle Action No. 379**



### MS-DOS®IMAGE ANALYSIS SOFTWARE

New! Axiom Research, Inc. MIRA (Microcomputer Image Reduction & Analysis) software: fast, full-featured, low-cost image display, reduction, and analysis for MS-DOS 5.0. Input 8-/16-bit integer, 32-bit real 1D/2D data, including CCD images to 2K X 2K with user-defined formats. Over 100 operations coded in assembly language for workstation graphical/numerical performance. Multi-window graphical interface.

**Saguaro Scientific Corporation**

**For More Information Circle Action No. 380**


### PALM-SIZE FFT ANALYZER

The remarkably small RION SA-77 FFT Analyzer weighs less than 24 ounces and performs like many lab types: 0-50 kHz, up to 800 lines, storage, order analysis, RS-232C, integration, etc. Analysis functions include FFT, phase, and amplitude distribution. The SA-77 complements Scantek's full line of sound and vibration instrumentation. Phone: 301-495-7738, Fax: 301-495-7739. Address is 916 Gist Ave., Silver Spring, MD 20910.

**Scantek, Inc.**

**For More Information Circle Action No. 381**

### ELECTRO-MAGNETICS ANALYSIS

Free demo disk and booklet: MagNet5 software featuring 2D/3D magnetostatic, electrostatic, and eddy current modelling and analysis on DOS, UNIX, VMS. Used worldwide since 1978 to improve designs and reduce prototyping. Phone: 514-849-8752, Fax: 514-849-4239.

**Infolytica Corporation**

**For More Information Circle Action No. 382**


### UKA OPTICAL PRODUCTS PLUS

Complete engineering, design and manufacturing of optical lenses and optical components. Custom design and off-the-shelf lenses with superior precision of computer design. Full sales and customer service support. Brochure available at your request.

**Universe Kogaku (America),**

**For More Information Circle Action No. 383**


### DEEP FREEZERS

Literature describes SCIENTEMP CORP.'s. high quality deep freezers ranging from -20 °C to -96 °C. Custom test equipment is our specialty. All products are "Made with Pride in the U.S.A." Call 517-263-6020, Fax: 517-263-5492 for more information. Address is 3565 S. Adrian Highway, Adrian, MI 49221-9251.

**SCIENTEMP CORP.**

**For More Information Circle Action No. 384**


### REVIEW OXYGEN ANALYZERS

A four-color brochure introduces a line of oxygen analyzers for the laboratory or process line. Suited for monitoring the oxygen levels in all types of gas streams. Trade oxygen levels from ppb to 100% are accurately determined by these ruggedly constructed instruments. No periodic maintenance or special operator skills required. Intrinsically safe and battery-operated versions are also available.

**Illinois Instruments, Inc.**

**For More Information Circle Action No. 385**


## FEDERAL PRIME CONTRACTS ON CD-ROM

Eagle Eye's Federal Prime Contracts on CD-ROM lists all activity on 90,000 annual federal contracts, 45,000 vendors, 2,500 product categories, 900 purchase offices and 200 federal agencies. Identify new sales leads, sub-contract opportunities, teaming partners and bidders! IBM-compatible. Phone: 703-242-4201. Address: 115 Park St., S.E., Vienna, VA 22180.

**Eagle Eye Publishers**

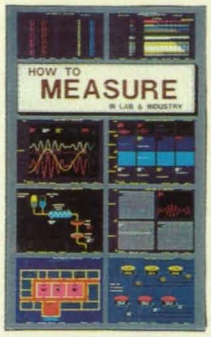
**For More Information Circle Action No. 386**


## LASER COMPONENTS -UV TO IR

A 32-page catalog of optical components and coatings for ultraviolet, visible and infrared applications, including lenses, windows, prisms, beamsplitters, mirrors, and filters. Broad range of zinc selenide, germanium and silicon optics for $CO_2$ lasers. Specialists in optical coatings for high-power applications.

**Laser Optics, Inc.**

**For More Information Circle Action No. 387**




## HIGH-RESOLUTION DATA ACQUISITION

FREE booklet shows many ways to automate data collection using your personal computer. It comes with a FREE Instatrend Real-Time Graphics Demo Disk.

**Dianachart, Inc.**

**For More Information Circle Action No. 388**


## BURR-BROWN DC/DC CONVERTERS

New! Catalog describes 500+ standard and unique Power Convertibles available in miniature SIP, DIP and industry standard modular packages. The handbook contains detailed product data sheets featuring regulated and unregulated units with wide input ranges and single, dual or triple outputs. Each product is built using surface mount construction and is a complete design solution—no external components required.

**Burr-Brown**

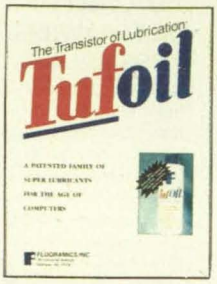
**For More Information Circle Action No. 389**


## HIGH-PERFORMANCE ALLOY

Elgiloy® is a high-performance nickel-cobalt alloy. This brochure describes its characteristics and properties as well as processing information. Elgiloy® is offered in strip and wire and is used in a variety of specialized applications.

**Elgiloy® Limited Partnership**

**For More Information Circle Action No. 390**




## TUFOIL OIL ADDITIVE—SLIPPERIER THAN TEFLON

So unique, it's patented. Spectacular low friction and wear confirmed by U.S. Government lab. Next time you change your oil, change it into a patented engine treatment. Enjoy fast starts, smooth operation, better acceleration, and longer engine life. Lubrication is our business!

**Fluoramics, Inc.**

**For More Information Circle Action No. 391**


## INFRARED IMAGING SYSTEM WITH STATIONARY IMAGE DISPLAY

Brochure describes our VideoTherm 92, a high resolution infrared imaging system that provides a Stationary Image Display (SID), allowing for fixed viewing of objects without panning. Accommodates temperature ranges from -30 °C to +1,375 °C in the 8-14 micron region. Features include polarity reversal of image, selectable freeze frame, and recursive filter selections. Request our free literature package today.

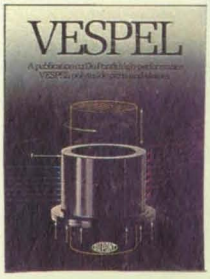
**For More Information Circle Action No. 392**


## REAL-TIME NETWORK

The SCRAMNet Network™ combines the real-time speed of replicated shared memory with the flexibility of a fiber optic LAN to get microsecond response from multi-vendor computers. It allows you to connect dissimilar computers at 150/Mbits/sec over fiber optics, with zero software overhead. This replicated shared memory network offers data filtering, programmable byte swapping, and a sophisticated interrupt structure. Phone: 513-252-5601 or 1-800-252-5601. Address is 4126 Linden Ave., Dayton, OH 45432-3068.

**Systran Corporation**

**For More Information Circle Action No. 393**




## FREE BOOK ON VESPEL® POLYIMIDE PARTS FROM DU PONT

When friction, wear and thermal problems combine with a need for strong and durable parts, there is an answer...VESPEL polyimide parts, made by Du Pont. Call today for your copy of this fact-filled 12-page book about VESPEL. Call toll-free 1-800-426-7246.

**Du Pont**

**For More Information Circle Action No. 394**


## GPS TIMING FOR PC AND VMEBUS

This information folder from Bancomm describes new PCbus and VMEbus board-level Global Positioning System (GPS) Satellite Receivers. These products provide worldwide precision time (100 nanosecond) and frequency (1 part in 10E7) references inside the host computer.

**Bancomm**

**For More Information Circle Action No. 395**


## NEW FIBER OPTICS PRODUCTS CATALOG

Just released a new 75-page catalog for fiber optic products. This catalog covers all the product categories for the installation, testing and maintenance of fiber optic systems. Included are attenuators, cable, cable assemblies, closures, connectors, patch panels, supplies, tools, test equipment, and splicing equipment. Also included are training manuals and videos. Phone: 206-251-1240, Fax: 206-251-1245.

**The Light Brigade, Inc.**

**For More Information Circle Action No. 396**

## SPACE PRODUCTS AND CAPABILITIES

Descriptions and specifications of Motorola's space products and capabilities, for both space and ground support equipment. Opens into a colorful wall chart showing the history of Motorola and electronic products.

**Motorola Strategic Electronics Division**

**For More Information Circle Action No. 397**

## 201,000 Reasons Why Your Ad Belongs Here

*NASA Tech Briefs'* Literature Spotlight section offers a low-cost way to reach over 201,000 industry and government LEADERS with your advertising message. These are technology managers, design engineers, and scientists with tremendous buying power. The **December 1992** issue is your next opportunity to use this high-impact sales tool. For more information or to reserve space in Literature Spotlight, contact your *NASA Tech Briefs* sales representative (listed on page 10 in this issue) or call Joseph Pramberger at (800) 944-NASA.


### COMPACT MeV MATERIALS ANALYSIS

This brochure describes the MAS1000 analysis instrument, which performs elemental analysis, depth profiling and channeling in crystals. In most cases the analysis is non-destructive and quantitative. The brochure describes the capabilities of standard RBS analysis as well as other analytical techniques capable with the MAS1000.

**National Electrostatics Corp.**

**For More Information Circle Action No. 399**


### CRYSTAL OSCILLATORS THICK FILM HYBRIDS

A brochure describes Hybrids' line of crystal oscillators. These precisely-engineered products are crafted using CMOS, HCMOS, TTL, ECL and GaAs Technologies and offer frequency ranges from 1Hz to 1GHz. Also TCXO's, VCXO's, and TCVCXO's in frequencies up to 500MHz are offered. Standard versions or customized oscillators can be ordered. Phone: 913-764-6400.

**Hybrids International, Ltd.**

**For More Information Circle Action No. 400**


### NEW CAPABILITIES BROCHURE

Over thirty years of experience summarized to show RdF's success in providing quality temperature sensors to the aerospace, military, nuclear, and commercial markets. RdF offers a combination of standard and custom designed RTD's, T/C's, Heat Flow Sensors, Foil Heaters, and more. Phone: 800-445-8367. Address: P.O. Box 490, Hudson, NH 03051-0490.

**RdF Corporation**

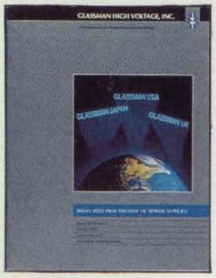
**For More Information Circle Action No. 401**


### TOOLING COMPONENTS & EQUIPMENT

New 376 page reference catalog offers a full range of tooling components and equipment. Items include handwheels, handles, knobs, spring & ball plungers, leveling pads, clamps, set up accessories, locating devices, cutting tools, rivets, thread inserts, hard to find tools and metric items. Contains complete specifications and pricing. All items are stocked for same day shipment. Phone: 800-253-0421, Fax: 616-773-4485.

**Reid Tool Supply Company**

**For More Information Circle Action No. 402**




### HIGH VOLTAGE DC POWER SUPPLIES

A 20-page, full color catalog details 14 series of regulated high voltage power supplies, 1 kV to 500 kV, 15 W to 15 kW. A quick selection guide, full specs, options, and ordering information aid the selection process. Phone: 908-534-9007, Fax: 908-534-5672.

**Glassman High Voltage, Inc.**

**For More Information Circle Action No. 403**


### APERTURE CARD PROCESSOR-CAMERA

The economical ALOS SMA 111 offers a revolutionary design in microfilming technology. Its user-friendly features, compact size and indifference to ambient light allows the ALOS SMA 111 to fit in work spaces where others cannot. Phone: 800-431-7105. Address: 118 Bracken Road, Montgomery, NY 12549-2604.

**ALOS Micrographics Corp.**

**For More Information Circle Action No. 404**


### TURBO-MACHINERY ENGINEERING

Free brochure shows how companies that produce or operate compressors, pumps, or turbines can benefit from NREC's advanced engineering consulting expertise, specialized CAE/CAM software, and precision manufacturing services. Phone: 617-937-4655, Fax: 617-935-9052.

**Northern Research & Engineering Corp.**

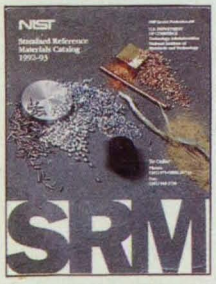
**For More Information Circle Action No. 405**


### PC SYSTEMS HANDBOOK

Designed for scientists and engineers, this handbook is a combination of tutorial information and a catalog of hard-to-find products for PC-based data acquisition, motion control, signal conditioning, and instrumentation. This new 1993 edition includes 196 pages of detailed technical and product information. Phone: 800-486-8800, Fax: 203-483-9024. Address: P.O. Box 9565, New Haven, CT 06535.

**CyberResearch**

**For More Information Circle Action No. 406**




### STANDARD REFERENCE MATERIALS CATALOG

The New Standard Reference Materials catalog from NIST lists some 1300 SRMs in 70 major categories. SRMs are well-characterized materials produced to improve measurement science and serve industry.

**National Institute of Standards and Technology**

**For More Information Circle Action No. 407**


### TECHNOLOGY SMALL BUSINESS SOURCEBOOK

Eagle Eye's 225-page High Technology Small Business Sourcebook profiles the larger 8 (a)/ Small Disadvantaged Businesses (SDB's) by market, by federal agency and by company.

• Identify teaming partners; • Identify acquisition candidates; • Find new vendors and clients; • Analyze the competition. Covers FY 1990-91. Phone: 703-242-4201. Address: 115 Park St., S.E., Vienna, VA 22180.

**Eagle Eye Publishers**

**For More Information Circle Action No. 408**

### CATALOG DESCRIBES DATA ACQUISITION SYSTEMS

Both general and specialized data acquisition systems are described in this new catalog from Hi-Techniques. Modular in design, these products contain all the software for acquisition of signal data, calculation of data parameters, and output of finished documentation for both research and routine test applications. Phone: 608-221-7500.

**Hi-Techniques, Inc.**

**For More Information Circle Action No. 409**

# Subject Index


## A

**ACOUSTIC EMISSION**
Tracking comb filter suppresses welder harmonics
page 44 MFS-29736

**ADHESIVE BONDING**
Laser shearography reveals hidden unbonds
page 101 MFS-29814

Preliminary design of adhesively bonded composite joints
page 78 LEW-15050

**AIRFOILS**
Positive stop for circulation-control slot
page 87 ARC-11764

**ALGORITHMS**
Optimizing reduced-order transfer functions
page 107 NPO-18358

Software for genetic algorithms
page 77 MSC-21904

**ALTIMETRY**
Radar altimetry for topographical mapping
page 37 NPO-18254

**ALUMINUM ALLOYS**
Indium helps strengthen Al/Cu/Li alloy
page 68 LAR-13924

**ALUMINUM**
Tests of polyurethane and dichromate coats on aluminum
page 73 MFS-27249

**ANGLES (GEOMETRY)**
Training for estimation of angles via perspective displays
page 113 ARC-12835

**ANODIZING**
Tests of polyurethane and dichromate coats on aluminum
page 73 MFS-27249

**ANTIICING ADDITIVES**
Polyphosphazene icephobic coating materials
page 67 NPO-18110

**ARRAYS**
Arraying techniques in the Deep Space Network
page 46 NPO-18455

**ARTIFICIAL INTELLIGENCE**
Artificial intelligence assists ultrasonic inspection
page 99 MFS-29817

C language integrated production system, version 5.0
page 74 MSC-21929/19/27

Dynamic restructuring of problems in artificial intelligence
page 103 NPO-18488

**ASTRONOMICAL CATALOGS**
Ties between celestial and planetary reference frames
page 64 NPO-18328

**ATMOSPHERIC CIRCULATION**
Aspects of 40- to 50-day oscillations in LOD and AAM
page 66 NPO-18378

**ATMOSPHERIC COMPOSITION**
Accuracy of the correlated-k method
page 63 NPO-18020

**ATOMIC SPECTRA**
Liquid-arc/spark-excitation atomic-emission spectroscopy
page 57 KSC-11540

## B

**BEAMS (SUPPORTS)**
Scaling of responses of composite beams
page 88 LAR-14366

**BEARINGS**
Improved superconducting magnetic rotary bearings
page 91 GSC-13346

**BESS (SATELLITE)**
U.S. biomedical experiments in a Soviet biosatellite
page 72 ARC-12795

**BIOMEDICAL DATA**
U.S. biomedical experiments in a Soviet biosatellite
page 72 ARC-12795

**BLUNT BODIES**
Nonequilibrium effects in hypervelocity flow
page 62 ARC-11760

**BRAZING**
Joining ceramics by brazing
page 97 LEW-15291

## C

**CALIBRATING**
Generating multiple calibrating voltages simultaneously
page 34 MFS-29830

**CARBON DIOXIDE LASERS**
Mode/medium instability in $CO_2$ laser
page 62 MFS-27250

**CARBON-CARBON COMPOSITES**
Carbon/carbon fasteners for use at high temperatures
page 71 MSC-21907

Carborane dopant strengthens pitch char
page 113 NPO-18214

**CARBORANE**
Carborane dopant strengthens pitch char
page 113 NPO-18214

**CELESTIAL REFERENCE SYSTEMS**
Ties between celestial and planetary reference frames
page 64 NPO-18328

**CERAMICS**
Joining ceramics by brazing
page 97 LEW-15291

**CHROMATES**
Tests of polyurethane and dichromate coats on aluminum
page 73 MFS-27249

**CIRCUITS**
Circuits protect against incorrect power connections
page 22 LEW-15294

Improving current balance in parallel MOSFET's
page 26 LEW-14886

**CIRCULATION CONTROL AIRFOILS**
Positive stop for circulation-control slot
page 87 ARC-11764

**COMPARTMENTS**
Habitable wardroom for Space Station Freedom
page 90 ARC-12762

**COMPOSITE MATERIALS**
Preliminary design of adhesively bonded composite joints
page 78 LEW-15050

**COMPOSITE STRUCTURES**
Scaling of responses of composite beams
page 88 LAR-14366

**COMPUTATIONAL GRIDS**
More about generating three-dimensional grids about anything
page 111 ARC-12276

**COMPUTER VISION**
Hand/eye coordination for fine robotic motion
page 103 NPO-18316

**COMPUTER AIDED DESIGN**
Automated simulation for analysis and design
page 110 ARC-12817

**COMPUTERIZED SIMULATION**
Analyzing robotic kinematics via computed simulations
page 110 GSC-13433

**CONSTRAINTS**
Fixed or controlled-movement foot restraint
page 81 MSC-21438

**CORRELATION**
Optical correlator with complex holographic filter
page 45 NPO-18464

**CORROSION RESISTANCE**
Alloys for flexible hoses in a corrosive environment
page 73 KSC-11480

**COSMOS SATELLITES**
U.S. biomedical experiments in a Soviet biosatellite
page 72 ARC-12795

**COUPLINGS**
Robots would couple and uncouple fluid and electrical lines
page 34 KSC-11467

**CRYOGENIC FLUID STORAGE**
Computing thermodynamics of cryostorage tanks in orbit
page 74 MFS-28583

**CRYOGENICS**
Optical link for readout from focal-plane array
page 30 NPO-18481

**CYBERNETICS**
Space-time neural networks
page 108 MSC-21874

**CYCLIC LOADS**
Ultrasonic dynamic vector stress sensor
page 85 LAR-14433

## D

**DATA COMPRESSION**
Fast vector-quantizing data compressor
page 42 NPO-17941

**DATA PROCESSING**
Front-end processor for metrology-information system
page 106 KSC-11470

Reconfigurable fuzzy cell
page 40 MSC-21613

**DEEP SPACE NETWORK**
Arraying techniques in the Deep Space Network
page 46 NPO-18455

**DEFECTS**
Laser shearography reveals hidden unbonds
page 101 MFS-29814

**DEICERS**
Polyphosphazene icephobic coating materials
page 67 NPO-18110

Windshield-wiper heater
page 86 LAR-14426

**DIRECTIONAL CONTROL**
Enhancing control of helicopter yaw at low speed
page 84 LAR-13630

**DISPLAY DEVICES**
Training for estimation of angles via perspective displays
page 113 ARC-12835

**DIURNAL VARIATIONS**
Aspects of 40- to 50-day oscillations in LOD and AAM
page 66 NPO-18378

**DYNAMIC CHARACTERISTICS**
Dynamics and control of flexible manipulator
page 96 NPO-18338

## E

**EARTH OBSERVING SYSTEM (EOS)**
Scanning-pencil-beam radar scatterometer
page 36 NPO-18300

**EARTH ROTATION**
Aspects of 40- to 50-day oscillations in LOD and AAM
page 66 NPO-18378

**ELECTRIC BATTERIES**
High-performance positive paste for lead/acid batteries
page 71 NPO-18205

**ELECTRIC CONDUCTORS**
Modified spot welder solders flat cables
page 100 GSC-13344

**ELECTRIC CONNECTORS**
Modified spot welder solders flat cables
page 100 GSC-13344

**ELECTRIC POWER SUPPLIES**
Circuits protect against incorrect power connections
page 22 LEW-15294

**ELECTRIC WELDING**
Tracking comb filter suppresses welder harmonics
page 44 MFS-29736


## Editor's Note

In the August issue (vol. 16 no. 8) several tech briefs had incorrect Technical Support Package (TSP) request numbers. These briefs are listed below with the correct TSP numbers. To order any of these TSPs, use the form on page 121 in this issue or call NASA's Center for AeroSpace Information at (410) 859-5300, ext. 245. Refer to the August issue for the full tech brief abstracts.

**Paraboloidal Reflector With Movable Subreflector** (Aug. p. 22)
NPO-18442
Circle 1 on the TSP Request Card.

**Capacitive Proximity Sensor Has Longer Range** (p. 22)
GSC-13377
Circle 3 on the TSP Request Card.

**Transmission of Power via Combined Laser Beams** (p. 34)
LAR-14389
Circle 5 on the TSP Request Card.

**Soot-Free Combustion of Methane and LNG** (p. 45)
MFS-28561
Circle 6 on the TSP Request Card.

**Nearly Azeotropic Mixtures to Replace Refrigerant 12** (p. 46)
NPO-18030
Circle 7 on the TSP Request Card.

**Removing Undesired Fine Powder From Silicon Reactor** (p. 47)
NPO-18323
Circle 8 on the TSP Request Card.

**Software for Integer Programming** (p. 50)
MFS-27260
Circle 9 on the TSP Request Card.

**Program for Logarithmic Interpolation of Test Data** (p. 51)
MFS-28551
Circle 11 on the TSP Request Card.

**Benchmark Lisp and Ada Programs** (p. 52)
ARC-12980
Circle 12 on the TSP Request Card.

**Tangential-Entry Injector With Internal Reed Valve** (p. 56)
MFS-28547
Circle 13 on the TSP Request Card.

**Improved Regenerative Sorbent-Compressor Refrigerator** (p. 61)
NPO-18211
Circle 15 on the TSP Request Card.

**Ultrasonic Probe for In Situ Inspection of Welds** (p. 63)
MFS-29842
Circle 16 on the TSP Request Card.

**Making Crystal Filaments From Extruded Ceramic Rods** (p. 68)
LEW-14921
Circle 17 on the TSP Request Card.

**ELECTRON BEAM WELDING**
Artificial intelligence assists ultrasonic inspection
page 99 MFS-29817

**ELECTRON ORBITALS**
Tables of Gaussian-type orbital basis functions
page 60 ARC-12647

**ELECTRON RADIATION**
Effects of irradiation by electrons on two polyimides
page 72 LAR-14309

**ELECTRONIC FILTERS**
Tracking comb filter suppresses welder harmonics
page 44 MFS-29736

**ELECTROPHORESIS**
Electrophoretic process for purifying wastewater
page 112 MFS-26149

**EMISSION SPECTRA**
Liquid-arc/spark-excitation atomic-emission spectroscopy
page 57 KSC-11540

**END EFFECTORS**
Compliant robot wrist
page 83 GSC-13357

Robotic gripper resists torsion and lateral forces
page 78 GSC-13356

Rolling-friction robotic gripper
page 92 GSC-13261

Split-rail, rolling-friction robotic gripper with tool d.ve
page 94 GSC-13370

**EPHEMERIDES**
Ties between celestial and planetary reference frames
page 64 NPO-18328

**EXERCISE PHYSIOLOGY**
Contraction-only exercise machine
page 81 KSC-11513

**EXPERT SYSTEMS**
Automated simulation for analysis and design
page 110 ARC-12817

C language integrated production system, version 5.0
page 74 MSC-21929/19/27

Dynamic restructuring of problems in artificial intelligence
page 103 NPO-18488

# F

**F-16 AIRCRAFT**
Tests of array of flush pressure sensors
page 89 ARC-12869

**FAN BLADES**
Screens would protect wind-tunnel fan blades
page 85 LAR-14197

**FAST FOURIER TRANSFORMATIONS**
Efficient two-dimensional-FFT program
page 76 GSC-13340

**FASTENERS**
Carbon/carbon fasteners for use at high temperatures
page 71 MSC-21907

**FEET (ANATOMY)**
Fixed or controlled-movement foot restraint
page 81 MSC-21438

**FIELD EFFECT TRANSISTORS**
Improving current balance in parallel MOSFET's
page 26 LEW-14886

**FINITE DIFFERENCE THEORY**
Scheme for finite-difference computations of waves
page 105 ARC-12970

**FINITE VOLUME METHOD**
More about generating three-dimensional grids about anything
page 111 ARC-12276

**FLAME SPECTROSCOPY**
Liquid-arc/spark-excitation atomic-emission spectroscopy
page 57 KSC-11540

**FOLDING STRUCTURES**
Foldable large reflectors
page 92 LAR-14513

**FOURIER TRANSFORMATION**
Efficient two-dimensional-FFT program
page 76 GSC-13340

**FUZZY SYSTEMS**
Reconfigurable fuzzy cell
page 40 MSC-21613

# G

**GALLIUM ARSENIDE LASERS**
Optical link for readout from focal-plane array
page 30 NPO-18481

**GAS LASERS**
Mode/medium instability in $CO_2$ laser
page 62 MFS-27250

**GERMANIUM ALLOYS**
Irradiation by neutrons and annealing of SiGe alloys
page 58 NPO-18313

# H

**HARMONICS**
Tracking comb filter suppresses welder harmonics
page 44 MFS-29736

**HASTELLOY (TRADEMARK)**
Alloys for flexible hoses in a corrosive environment
page 73 KSC-11480

**HEAT TOLERANCE**
How humans adapt to heat
page 112 ARC-12596

**HEAT TRANSFER**
Making conductive, compliant heat-transfer pads
page 98 NPO-18562

**HELICOPTERS**
Enhancing control of helicopter yaw at low speed
page 84 LAR-13630

**HETEROJUNCTION DEVICES**
SNS heterojunctions with new combinations of materials
page 22 NPO-18483

**HIGH TEMPERATURE ENVIRONMENTS**
Carbon/carbon fasteners for use at high temperatures
page 71 MSC-21907

**HIGH TEMPERATURE SUPERCONDUCTORS**
Improved superconducting magnetic rotary bearings
page 91 GSC-13346

SNS heterojunctions with new combinations of materials
page 22 NPO-18483

Superconductive coplanar-waveguide filters
page 26 NPO-18424

Superconducting films on microwave dielectric substrates
page 67 LEW-15011

**HOLOGRAPHIC INTERFEROMETRY**
Optical correlator with complex holographic filter
page 45 NPO-18464

**HOLOGRAPHY**
Laser shearography reveals hidden unbonds
page 101 MFS-29814

**HOSES**
Alloys for flexible hoses in a corrosive environment
page 73 KSC-11480

**HUMAN TOLERANCES**
How humans adapt to heat
page 112 ARC-12596

**HYDRAULIC EQUIPMENT**
Electrically controlled valve with small motor
page 95 MSC-21665

**HYPERSONIC FLOW**
Two algorithms for hypersonic computations
page 82 ARC-12676

**HYPERVELOCITY FLOW**
Nonequilibrium effects in hypervelocity flow
page 62 ARC-11760

# I

**ICE PREVENTION**
Polyphosphazene icephobic coating materials
page 67 NPO-18110

**IMAGING SPECTROMETERS**
Programmable hyperspectral imaging mapper
page 36 NPO-17794

**INCONEL (TRADEMARK)**
Alloys for flexible hoses in a corrosive environment
page 73 KSC-11480

**INDIUM ALLOYS**
Indium helps strengthen Al/Cu/Li alloy
page 68 LAR-13924

**INFRARED DETECTORS**
Optical link for readout from focal-plane array
page 30 NPO-18481

**INSPECTION**
In situ robotic inspection of welds
page 99 MFS-29844

Laser shearography reveals hidden unbonds
page 101 MFS-29814

**INTELLIGENCE**
Dynamic restructuring of problems in artificial intelligence
page 103 NPO-18488

**IRRADIANCE**
Accuracy of the correlated-k method
page 63 NPO-18020

# J

**JOINTS (JUNCTIONS)**
Carbon/carbon fasteners for use at high temperatures
page 71 MSC-21907

Preliminary design of adhesively bonded composite joints
page 78 LEW-15050

Robot would assemble collet/flexible-drive truss joint
page 97 MSC-21648

# K

**KINEMATICS**
Analyzing robotic kinematics via computed simulations
page 110 GSC-13433

# L

**LAMINATES**
Tailoring laminates for protection against projectiles
page 68 MFS-26153

**LASER APPLICATIONS**
Laser shearography reveals hidden unbonds
page 101 MFS-29814

**LASERS**
Mode/medium instability in $CO_2$ laser
page 62 MFS-27250

**LEAD ACID BATTERIES**
High-performance positive paste for lead/acid batteries
page 71 NPO-18205

**LIGHT ALLOYS**
Indium helps strengthen Al/Cu/Li alloy
page 68 LAR-13924

**LIGHTNING**
Lightning-sensor data help in understanding thunderstorms
page 65 MFS-27263

# M

**MAGNETIC BEARINGS**
Improved superconducting magnetic rotary bearings
page 91 GSC-13346

**MANAGEMENT INFORMATION SYSTEMS**
Front-end processor for metrology-information system
page 106 KSC-11470

**MANIPULATORS**
Compliant robot wrist
page 83 GSC-13357

Dynamics and control of flexible manipulator
page 96 NPO-18338

Hand/eye coordination for fine robotic motion
page 103 NPO-18316

Robotic gripper resists torsion and lateral forces
page 78 GSC-13356

Rolling-friction robotic gripper
page 92 GSC-13261

Split-rail, rolling-friction robotic gripper with tool drive
page 94 GSC-13370

Study of robotic replacement of equipment modules
page 96 NPO-18152

**MAPPING**
Programmable hyperspectral imaging mapper
page 36 NPO-17794

Radar altimetry for topographical mapping
page 37 NPO-18254

**MECHANICAL DEVICES**
Positive stop for circulation-control slot
page 87 ARC-11764

**MEMORY (COMPUTERS)**
Publication of oceanographic data on CD-ROM
page 44 NPO-18270

**METAL MATRIX COMPOSITES**
Making conductive, compliant heat-transfer pads
page 98 NPO-18562

**METEOROID PROTECTION**
Multishock shield against meteoroids and debris
page 72 MSC-21420

**METEOROLOGY**
Lightning-sensor data help in understanding thunderstorms
page 65 MFS-27263

**METROLOGY**
Front-end processor for metrology-information system
page 106 KSC-11470

**MICROMETEOROIDS**
Multishock shield against meteoroids and debris
page 72 MSC-21420

**MILLIMETER WAVES**
Photofabricated wire-grid polarizers
page 32 NPO-18272

**MUSCULAR TONUS**
Contraction-only exercise machine
page 81 KSC-11513

# N

**NATIONAL AEROSPACE PLANE PROGRAM**
Carbon/carbon fasteners for use at high temperatures
page 71 MSC-21907

**NAVIER-STOKES EQUATION**
Two algorithms for hypersonic computations
page 82 ARC-12676

**NETS**
Space-time neural networks
page 108 MSC-21874

**NEURAL NETS**
Space-time neural networks
page 108 MSC-21874

**NEUTRON IRRADIATION**
Irradiation by neutrons and annealing of SiGe alloys
page 58 NPO-18313

**NICKEL ALLOYS**
Alloys for flexible hoses in a corrosive environment
page 73 KSC-11480

**NONEQUILIBRIUM FLOW**
Nonequilibrium effects in hypervelocity flow
page 62 ARC-11760

**NOSE WHEELS**
Sleeve protects axle when wheel is changed
page 80 KSC-11434

**NUMERICAL ANALYSIS**
Scheme for finite-difference computations of waves
page 105 ARC-12970

# O

**OCEANOGRAPHIC PARAMETERS**
Publication of oceanographic data on CD-ROM
page 44 NPO-18270

**OPTICAL COMMUNICATION**
Optical link for readout from focal-plane array
page 30 NPO-18481

**OPTICAL DATA PROCESSING**
Optical correlator with complex holographic filter
page 45 NPO-18464

**OPTICAL DATA STORAGE MATERIALS**
Publication of oceanographic data on CD-ROM
page 44 NPO-18270

**OPTICAL FILTERS**
Optical correlator with complex holographic filter
page 45 NPO-18464

**OPTIMIZATION**
Optimizing reduced-order transfer functions
page 107 NPO-18358

Software for genetic algorithms
page 77 MSC-21904

**ORBITALS**
Tables of Gaussian-type orbital basis functions
page 60 ARC-12647

**OVERVOLTAGE**
Circuits protect against incorrect power connections
page 22 LEW-15294

## P

**PARABOLIC REFLECTORS**
Foldable large reflectors
page 92 LAR-14513

**PHOSPHAZENE**
Polyphosphazene icephobic coating materials
page 67 NPO-18110

**PITCH (MATERIAL)**
Carborane dopant strengthens pitch char
page 113 NPO-18214

**PHYSICAL EXERCISE**
Contraction-only exercise machine
page 81 KSC-11513

**PHYSIOLOGY**
How humans adapt to heat
page 112 ARC-12596

**PLANET EPHEMERIDES**
Ties between celestial and planetary reference frames
page 64 NPO-18328

**POISSON EQUATION**
More about generating three-dimensional grids about anything
page 111 ARC-12276

**POLARIZERS**
Photofabricated wire-grid polarizers
page 32 NPO-18272

**POLYIMIDES**
Effects of irradiation by electrons on two polyimides
page 72 LAR-14309

**POLYMERIC FILMS**
Slow-positron generator for studying polymer films
page 57 LAR-14250

**POLYURETHANE RESINS**
Tests of polyurethane and dichromate coats on aluminum
page 73 MFS-27249

**POSITRONS**
Slow-positron generator for studying polymer films
page 57 LAR-14250

**POTABLE WATER**
Electrophoretic process for purifying wastewater
page 112 MFS-26149

**PREPROCESSING**
Reconfigurable fuzzy cell
page 40 MSC-21613

**PRESSURE REGULATORS**
Electrically controlled valve with small motor
page 95 MSC-21665

**PRESSURE SENSORS**
Tests of array of flush pressure sensors
page 89 ARC-12869

**PROJECTILES**
Tailoring laminates for protection against projectiles
page 68 MFS-26153

**PROTECTIVE COATINGS**
Tests of polyurethane and dichromate coats on aluminum
page 73 MFS-27249

## R

**RADAR SCATTERING**
Scanning-pencil-beam radar scatterometer
page 36 NPO-18300

**RADIATION DAMAGE**
Irradiation by neutrons and annealing of SiGe alloys
page 58 NPO-18313

**RADIATION EFFECTS**
Effects of irradiation by electrons on two polyimides
page 72 LAR-14309

**REFLECTORS**
Foldable large reflectors
page 92 LAR-14513

**REMOTE CONTROL**
Dynamics and control of flexible manipulator
page 96 NPO-18338

Study of robotic replacement of equipment modules
page 96 NPO-18152

**REMOTE SENSING**
Programmable hyperspectral imaging mapper
page 36 NPO-17794

**RETAINING**
Fixed or controlled-movement foot restraint
page 81 MSC-21438

**ROBOTICS**
Analyzing robotic kinematics via computed simulations
page 110 GSC-13433

Compliant robot wrist
page 83 GSC-13357

Hand/eye coordination for fine robotic motion
page 103 NPO-18316

In situ robotic inspection of welds
page 99 MFS-29844

Robot would assemble collet/flexible-drive truss joint
page 97 MSC-21648

Robotic gripper resists torsion and lateral forces
page 78 GSC-13356

Rolling-friction robotic gripper
page 92 GSC-13261

Split-rail, rolling-friction robotic gripper with tool drive
page 94 GSC-13370

Study of robotic replacement of equipment modules
page 96 NPO-18152

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**ROBOTS**
Robots would couple and uncouple fluid and electrical lines
page 34 KSC-11467

**ROOMS**
Habitable wardroom for Space Station Freedom
page 90 ARC-12762

# S

**SAFETY DEVICES**
Windshield-wiper heater
page 86 LAR-14426

**SATELLITE BORNE RADAR**
Radar altimetry for topographical mapping
page 37 NPO-18254

**SCALE MODELS**
Scaling of responses of composite beams
page 88 LAR-14366

**SCATTEROMETERS**
Scanning-pencil-beam radar scatterometer
page 36 NPO-18300

**SEMICONDUCTOR LASERS**
Optical link for readout from focal-plane array
page 30 NPO-18481

**SHAFTS (MACHINE ELEMENTS)**
Sleeve protects axle when wheel is changed
page 80 KSC-11434

**SHIELDING**
Screens would protect wind-tunnel fan blades
page 85 LAR-14197

Tailoring laminates for protection against projectiles
page 68 MFS-26153

**SIGNAL GENERATORS**
Generating multiple calibrating voltages simultaneously
page 34 MFS-29830

**SIGNAL PROCESSING**
Arraying techniques in the Deep Space Network
page 46 NPO-18455

**SILICON ALLOYS**
Irradiation by neutrons and annealing of SiGe alloys
page 58 NPO-18313

**SOFTWARE ENGINEERING**
C language integrated production system, version 5.0
page 74 MSC-21929/19/27

**SOFTWARE TOOLS**
Software for genetic algorithms
page 77 MSC-21904

**SOLDERING**
Modified spot welder solders flat cables
page 100 GSC-13344

**SPACE COMMUNICATION**
Arraying techniques in the Deep Space Network
page 46 NPO-18455

**SPACE ERECTABLE STRUCTURES**
Active suppression of vibrations in a truss
page 88 NPO-18305

**SPACE LOGISTICS**
Computing thermodynamics of cryostorage tanks in orbit
page 74 MFS-28583

**SPACE STATIONS**
Habitabe wardroom for Space Station Freedom
page 90 ARC-12762

**SPACECRAFT CABINS**
Habitable wardroom for Space Station Freedom
page 90 ARC-12762

**SPACECRAFT SHIELDING**
Multishock shield against meteoroids and debris
page 72 MSC-21420

Tailoring laminates for protection against projectiles
page 68 MFS-26153

**SPATIAL FILTERING**
Optical correlator with complex holographic filter
page 45 NPO-18464

**SPECTROSCOPY**
Liquid-arc/spark-excitation atomic-emission spectroscopy
page 57 KSC-11540

Slow-positron generator for studying polymer films
page 57 LAR-14250

**SPECTRUM ANALYSIS**
Accuracy of the correlated-k method
page 63 NPO-18020

**SPOT WELDS**
Modified spot welder solders flat cables
page 100 GSC-13344

**STOPPING**
Positive stop for circulation-control slot
page 87 ARC-11764

**STORAGE BATTERIES**
High-performance positive paste for lead/acid batteries
page 71 NPO-18205

**STORAGE TANKS**
Computing thermodynamics of cryostorage tanks in orbit
page 74 MFS-28583

**STRESS MEASUREMENT**
Ultrasonic dynamic vector stress sensor
page 85 LAR-14433

**STRUCTURAL VIBRATION**
Active suppression of vibrations in a truss
page 88 NPO-18305

**SUBMILLIMETER WAVES**
Photofabricated wire-grid polarizers
page 32 NPO-18272

**SUPERCONDUCTORS**
Improved superconducting magnetic rotary bearings
page 91 GSC-13346

SNS heterojunctions with new combinations of materials
page 22 NPO-18483

superconducting films on microwave dielectric substrates
page 67 LEW-15011

Superconductive coplanar-waveguide filters
page 26 NPO-18424

**SYNTHETIC APERTURE RADAR**
Fast vector-quantizing data compressor
page 42 NPO-17941

Radar altimetry for topographical mapping
page 37 NPO-18254

**SYSTEMS ANALYSIS**
Automated simulation for analysis and design
page 110 ARC-12817

# T

**TELEMETRY**
Fast vector-quantizing data compressor
page 42 NPO-17941

**TELEOPERATORS**
Hand/eye coordination for fine robotic motion
page 103 NPO-18316

**THERMAL CONDUCTORS**
Making conductive, compliant heat-transfer pads
page 98 NPO-18562

**THERMODYNAMIC PROPERTIES**
Computing thermodynamics of cryostorage tanks in orbit
page 74 MFS-28583

**THERMOELECTRIC MATERIALS**
Irradiation by neutrons and annealing of SiGe alloys
page 58 NPO-18313

**THUNDERSTORMS**
Lightning-sensor data help in understanding thunderstorms
page 65 MFS-27263

**TOOLS**
Split-rail, rolling-friction robotic gripper with tool drive
page 94 GSC-13370

**TOPOGRAPHY**
Radar altimetry for topographical mapping
page 37 NPO-18254

**TRAINING DEVICES**
Training for estimation of angles via perspective displays
page 113 ARC-12835

**TRANSFER FUNCTIONS**
Optimizing reduced-order transfer functions
page 107 NPO-18358

**TRANSFORMATIONS (MATHEMATICS)**
Efficient two-dimensional-FFT program
page 76 GSC-13340

**TRANSISTORS**
Improving current balance in parallel MOSFET's
page 26 LEW-14886

**TRUSSES**
Active suppression of vibrations in a truss
page 88 NPO-18305

Robot would assemble collet/flexible-drive truss joint
page 97 MSC-21648

# U

**ULTRASONIC FLAW DETECTION**
Artificial intelligence assists ultrasonic inspection
page 99 MFS-29817

**ULTRASONIC TESTS**
Ultrasonic dynamic vector stress sensor
page 85 LAR-14433

**UMBILICAL CONNECTORS**
Robots would couple and uncouple fluid and electrical lines
page 34 KSC-11467

# V

**VALVES**
Electrically controlled valve with small motor
page 95 MSC-21665

**VAPOR DEPOSITION**
superconducting films on microwave dielectric substrates
page 67 LEW-15011

**VEHICLE WHEELS**
Sleeve protects axle when wheel is changed
page 80 KSC-11434

**VIBRATION DAMPING**
Active suppression of vibrations in a truss
page 88 NPO-18305

**VIDEO DISKS**
Publication of oceanographic data on CD-ROM
page 44 NPO-18270

**VISCOUS FLOW**
Two algorithms for hypersonic computations
page 82 ARC-12676

**VOLTAGE GENERATORS**
Generating multiple calibrating voltages simultaneously
page 34 MFS-29830

# W

**WASTE WATER**
Electrophoretic process for purifying wastewater
page 112 MFS-26149

**WATER TREATMENT**
Electrophoretic process for purifying wastewater
page 112 MFS-26149

**WAVE FUNCTIONS**
Tables of Gaussian-type orbital basis functions
page 60 ARC-12647

**WAVE PROPAGATION**
Scheme for finite-difference computations of waves
page 105 ARC-12970

**WAVEGUIDE FILTERS**
Superconductive coplanar-waveguide filters
page 26 NPO-18424

**WELDING**
In situ robotic inspection of welds
page 99 MFS-29844

Joining ceramics by brazing
page 97 LEW-15291

**WIND TUNNEL TESTS**
Tests of array of flush pressure sensors
page 89 ARC-12869

**WIND TUNNELS**
Screens would protect wind-tunnel fan blades
page 85 LAR-14197

**WINDSHIELDS**
Windshield-wiper heater
page 86 LAR-14426

**WIRE GRID LENSES**
Photofabricated wire-grid polarizers
page 32 NPO-18272

# Y

**YAW**
Enhancing control of helicopter yaw at low speed
page 84 LAR-13630

# ADVERTISERS INDEX


| | | |
|---|---|---|
| 3M Electrical Specialties Division | (RAC 436)* | 102 |
| Abaris Training Resources, Inc. | (RAC 333) | 125 |
| ABB K-Flow, Inc. | (RAC 359) | 128 |
| Accurate Screw Machine Co. | (RAC 345) | 126 |
| Adac Corporation | (RAC 611) | 101 |
| ADMAX Computer, Inc. | (RAC 651) | 135 |
| Aerotech | (RAC 331) | 125 |
| Aero Tec Laboratories, Inc. | (RAC 588) | 89 |
| Algor Interactive Systems, Inc. | (RAC 449) | 60 |
| ALOS Micrographics Corp. | (RAC 404) | 131 |
| Allied-Signal, Inc. | (RAC 515) | 5 |
| Amco Engineering Company | (RAC 500) | 24 |
| American Variseal | (RAC 534,572) | 116,134 |
| Ansoft Corporation | (RAC 348) | 127 |
| Apex Microtechnology Corporation | (RAC 585,347) | 30,127 |
| AP Labs | (RAC 626) | 76 |
| Apple Rubber Products | (RAC 320) | 124 |
| Aries Technology | (RAC 322) | 125 |
| Astro-Med, Inc. | (RAC 602) | 43 |
| AT&T Software Solutions Group | (RAC 374) | 128 |
| Autodesk, Inc. | (RAC 504) | 1 |
| Avtech Electrosystems | (RAC 435) | 134 |
| Avtec Systems, Inc. | (RAC 536) | 32 |
| Bal Seal Engineering Co., Inc. | (RAC 379) | 129 |
| Balzers | (RAC 604) | 89 |
| Bancomm | (RAC 395) | 130 |
| Battery Engineering, Inc. | (RAC 486) | 104 |
| BEI Motion Systems Company | (RAC 343) | 126 |
| Berg Systems International, Inc. | (RAC 668) | 18 |
| Boker's, Inc. | (RAC 304) | 123 |
| Burr-Brown | (RAC 389) | 130 |
| Cadam, Inc. | (RAC 358) | 128 |
| Carr Lane Mfg. | (RAC 324) | 125 |
| Cincinnati Electronics | (RAC 317) | 124 |
| Compumotor Division,Parker Hannifin Corp. | (RAC 340) | 126 |
| Computer Associates International, Inc. | (RAC 615) | 19 |
| Concurrent Computer Corp. | (RAC 661) | 23 |
| Contec Microelectronics USA, Inc. | (RAC 319) | 124 |
| Contempory Cybernetics Group | (RAC 417) | COV II |
| Cyber Research, Inc. | (RAC 360-373,406) | 35,131 |
| Daedal Division,Parker Hannifin Corporation | (RAC 341) | 126 |
| Davis Instrument Mfg. Co., Inc. | (RAC 363) | 128 |
| Dataq Instruments, Inc. | (RAC 414) | 135 |
| Dage-MTI, Inc. | (RAC 346) | 127 |
| Data Translation | (RAC 549) | 27 |
| Datum, Inc. | (RAC 586) | 14 |
| DCC Corporation | (RAC 351) | 127 |
| Dianachart, Inc. | (RAC 388) | 130 |
| Dipix Technologies, Inc. | (RAC 480) | 134 |
| Du Pont | (RAC 394) | 130 |
| Dynair Electronics, Inc. | (RAC 376) | 129 |
| Eagle Eye Publishers | (RAC 386,408) | 130,131 |
| Edmund Scientific Co. | (RAC 378) | 129 |
| Elgiloy Limited Partnership | (RAC 612,390) | 93,130 |
| Elmwood Sensors | (RAC 565) | 48 |
| Emcor Products | (RAC 332) | 125 |
| EPIX, Inc. | (RAC 675) | 135 |
| Evolution Computing | (RAC 328) | 125 |
| Exergen Corporation | (RAC 613) | 94 |
| Fabco-Air, Inc. | (RAC 316) | 124 |
| Fluoramics, Inc. | (RAC 514,391) | 107,130 |
| Folsom Research | (RAC 540) | 45 |
| Frequency Electronics, Inc. | (RAC 640) | 61 |
| F.W. Bell | (RAC 443) | 28 |
| Galil Motion Control, Inc. | (RAC 330) | 125 |
| General Air Corporation | (RAC 367) | 128 |
| General Control Devices | (RAC 655) | 135 |
| General Devices | (RAC 315) | 124 |
| General Magnaplate | (RAC 314) | 124 |
| Glassman High Voltage, Inc. | (RAC 544,403) | 33,131 |
| Gould, Inc. | (RAC 484,327) | 21,125 |
| Graham-White Mfg. Company | (RAC 338) | 126 |
| Graphics Simulation Group, ATR | (RAC 321) | 124 |
| Graseby IR Systems | (RAC 362) | 128 |
| Hardigg Cases | (RAC 478) | 37 |
| Hemco Corporation | (RAC 313) | 124 |
| Hi-Techniques, Inc. | (RAC 409) | 131 |
| Hughes Aircraft Company | | 9 |
| Hunter Products, Inc. | (RAC 329) | 125 |
| Hybrids International, Ltd. | (RAC 400) | 131 |
| HyperLogic Corporation | (RAC 630) | 134 |
| Hyperception, Inc. | (RAC 505) | COV IV |
| IBM Corporation | | 16-17 |
| Illbruck, Inc. | (RAC 368) | 128 |
| Illinois Instruments, Inc. | (RAC 385) | 129 |
| INCO Specialty Powder Products | (RAC 652) | 69 |
| Industrial Devices Corporation | (RAC 312) | 124 |
| Infolytica Corporation | (RAC 382) | 129 |
| Inframetrics | (RAC 354) | 127 |
| Inland Vacuum Industries, Inc. | (RAC 325) | 125 |
| Integrated Systems, Inc. | (RAC 567) | 77 |
| ISCAN, Inc. | (RAC 447) | 88 |
| I.S.I. Group, Inc. | (RAC 392) | 130 |
| Jandel Scientific | (RAC 352) | 127 |
| Jane's Information Group, Inc. | (RAC 369) | 128 |
| John Fluke Mfg. Co., Inc. | (RAC 512) | 47 |
| Kalamazoo Technical Furniture, Inc. | (RAC 311) | 124 |
| Kaman Instrumentation Corp. | (RAC 592,644) | 4,15 |
| Kano Laboratories | (RAC 452) | 134 |
| Keithley MetraByte | (RAC 619) | COV III |
| Laser Optics, Inc. | (RAC 387) | 130 |
| LaQue Center for CorrosionTechnology, Inc. | (RAC 309) | 123 |
| Lucas Schaevitz | (RAC 310) | 124 |
| Macsyma, Inc. | (RAC 614) | 111 |
| Magnetic Shield Corp./Perfection Mica Co. | (RAC 607) | 62 |
| Master Bond, Inc. | (RAC 444) | 104 |
| MathSoft, Inc. | (RAC 421) | 29 |
| Mechanical Dynamics | (RAC 603) | 63 |
| Melles Griot | (RAC 455) | 65 |
| Meridian Laboratory | (RAC 488) | 105 |
| Microstar Laboratories | (RAC 450) | 134 |
| MicroTek International, Inc. | (RAC 308) | 123 |
| Minco Products, Inc. | (RAC 541) | 106 |
| MIT/CAES | (RAC 606) | 112 |
| MIT/Enterprise Forum | (RAC 648) | 117 |
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| National Electrostatics Corp. | (RAC 399) | 131 |
| National Instruments | (RAC 681,307) | 3,123 |
| National Institute of Standards and Technology | (RAC 407) | 131 |
| National Standards Association | (RAC 460) | 84 |
| Neslab Instruments, Inc. | (RAC 353) | 127 |
| NeuralWare, Inc. | (RAC 658) | 109 |
| Nicolet Instruments Corp. | (RAC 526) | 70 |
| Northern Research and Engineering Corporation | (RAC 405) | 131 |
| Numerical Algorithms Group | (RAC 428) | 59 |
| Odetics | (RAC 547) | 66 |
| OrCAD L.P. | (RAC 306) | 123 |
| Pave Technology Co., Inc. | (RAC 491) | 32 |
| Patton & Patton Software Corporation | (RAC 499) | 79 |
| Penn Engineering & Mfg. Corp. | (RAC 670) | 135 |
| Pentek, Inc. | (RAC 334) | 126 |
| Philtec, Inc. | (RAC 337) | 126 |
| Planar | (RAC 609) | 38 |
| Polytec | (RAC 305) | 123 |
| Precision Metalsmiths, Inc. | (RAC 303) | 123 |
| Quinn-Curtis | (RAC 375) | 129 |
| RdF Corporation | (RAC 401) | 131 |
| Reid Tool Supply Company | (RAC 402) | 131 |
| Rexham Industrial | (RAC 521) | 93 |
| RGB Spectrum | (RAC 467,469,479,349) | 10,42,46,127 |
| Rolyn Optics Co. | (RAC 326,458) | 125,134 |
| Saguaro Scientific Corporation | (RAC 370,377,380) | 128,129 |
| Seal Master Corporation | (RAC 628) | 86 |
| Scantek, Inc. | (RAC 381) | 129 |
| Selco Products Company | (RAC 372) | 128 |
| Scientemp Corporation | (RAC 384) | 129 |
| SEMicro Corporation | (RAC 318) | 124 |
| Servometer Corporation | (RAC 465) | 115 |
| Small Parts, Inc. | (RAC 302) | 123 |
| Spectra Gases | (RAC 357) | 127 |
| Spyglass, Inc. | (RAC 654,656) | 11 |
| Staeubli Unimation, Inc. | (RAC 342) | 126 |
| Stanford Research Systems | (RAC 445,364) | 39,128 |
| Structural Research &Analysis Corporation | (RAC 446) | 83 |
| Surfware, Inc. | (RAC 350) | 127 |
| Systran Corporation | (RAC 393,432) | 130,134 |
| TEAC America, Inc. | (RAC 493) | 2 |
| Technology 2002 | | 49-56 |
| Techron | (RAC 671) | 31 |
| Teledyne Solid State | (RAC 517) | 41 |
| The Light Brigade, Inc. | (RAC 396) | 130 |
| The MathWorks, Inc. | (RAC 503) | 7 |
| The Staver Company | (RAC 356) | 127 |
| Tiodize Company, Inc. | (RAC 336) | 126 |
| Titan Tool Supply Company | (RAC 669) | 135 |
| Tustin Technical Institute, Inc. | (RAC 301) | 123 |
| Universe Kogaku (America) | (RAC 383) | 129 |
| Velmex, Inc. | (RAC 605) | 88 |
| Vibration Test Systems | (RAC 335) | 126 |
| Walker Scientific, Inc. | (RAC 365) | 128 |
| W.M. Berg, Inc. | (RAC 355) | 127 |
| Zero Plastics | (RAC 535) | 64 |
| Zircar Products, Inc. | (RAC 621,323,339) | 86,125,126 |
| Z-World Engineering | (RAC 439) | 134 |


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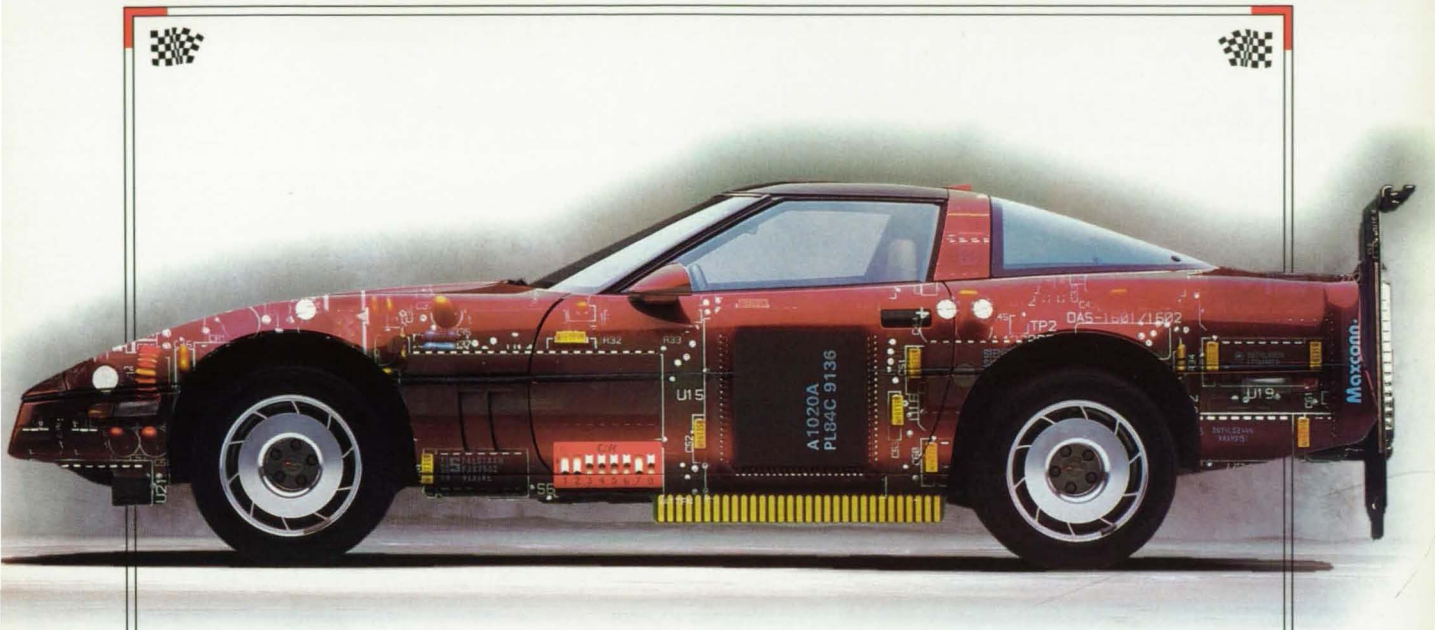


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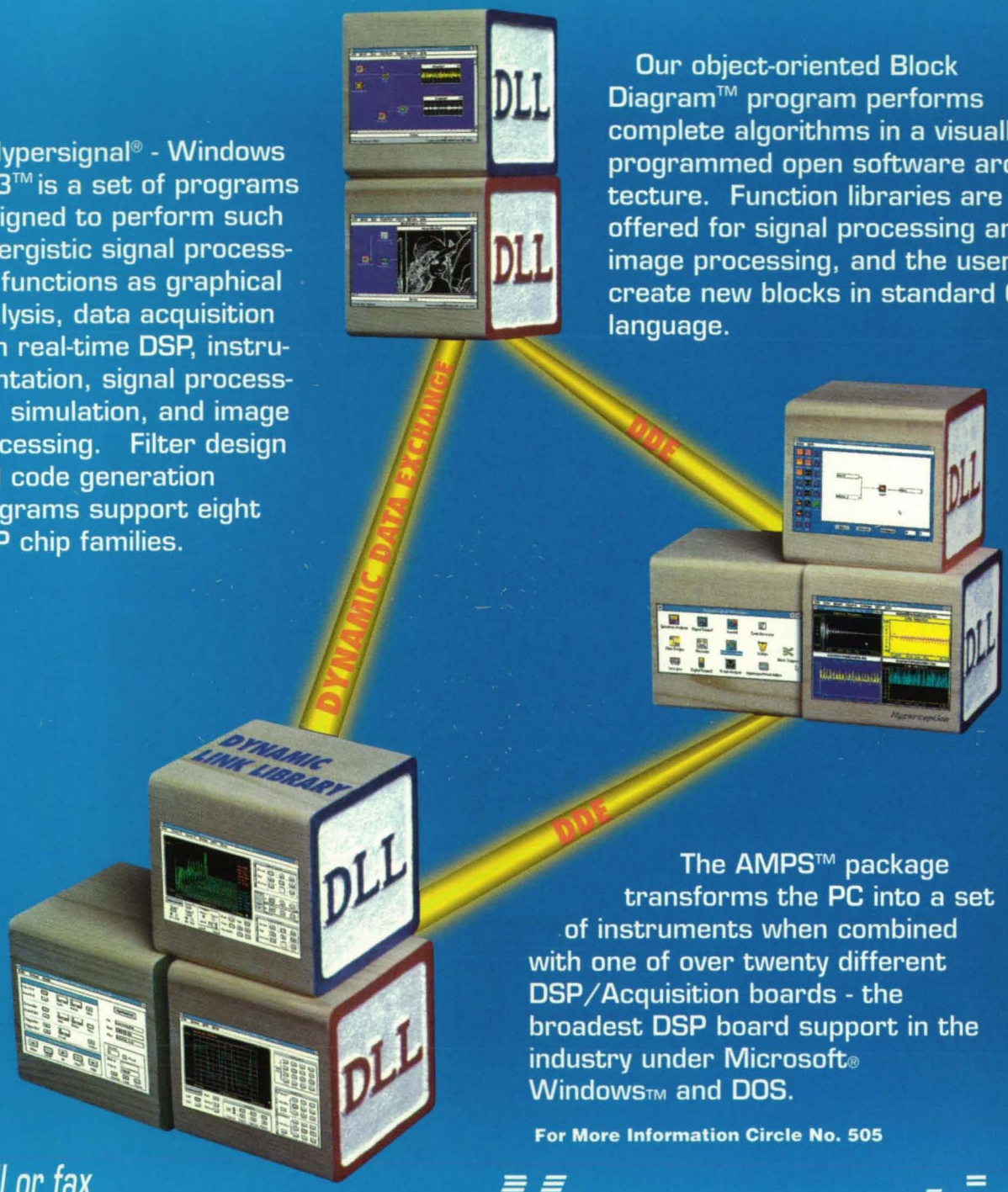


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